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U. S. Official Photo.] From Underwood & Underwood

Taking the camera aboard an American scout plane

RECENT PROGRESS IN AERIAL PHOTOGRAPHY **(See p. 136)**

Viscosity*

The Nature of Viscosity, How It Has Been Estimated and Measured, Its Value in Every-Day Life

By Nicolas Flamel

Viscous substances, of which but little is known by the general public, have nevertheless played a highly important part in the war. The difficulties experienced in winter by gunners because of the poor functioning of the oil recoil-brakes have borne vexatious witness to the action exerted by temperature on that property of matter known as viscosity; while on the other hand it is by means of the inertia of viscous bodies that Georges Claude has succeeded in devising a new gun carriage.

We do not purpose to consider the viscosity of gases in the present article. We may say merely that it is measured by the same methods as the viscosity of liquids. The degree of magnitude and the variations due to temperature are the only things that differ. In order to fix at once some notion of the numerical values attached to the varying degrees of viscosity, we may remark here that hydrogen gas has a viscosity of 0.000089; chlorine gas 0.000145; air 0.00018; water a figure somewhat in excess of 0.01; mercury about 0.016; glycerine 10.2; shoemaker's wax 2,000,000,000. All these figures are for a temperature of 15°C.

Viscosity is a physical magnitude which corresponds to *internal friction*, i. e. to the friction of the molecules or of the groups of molecules of a body upon each other. In the case of a liquid—and it is this of which we shall here speak, since it is in this state of matter that the knowledge of viscosity is of the greatest importance—it may be said that viscosity has to do with the aptitude possesed by the liquid to assume more or less rapidly the form of the free space into which it is poured. The more rapidly the free surface of a liquid approaches a level surface, and generally speaking a horizontal plane, the less the degree of viscosity possessed by the said liquid. Thus the most superficial observation enables us to distinguish the difference in viscosity between water and molasses or other syrup.

Furthermore, it is not always possible to draw a very clear line of demarcation between a liquid and a solid. Hendrick remarks that mercury is a liquid because "you can't pick it up." Those who enjoy cheese will recall that Camembert is sometimes a solid while at other times it possesses the consistency of a liquid. Shoemaker's wax, which is so brittle that the fragmentation obtained when a sheet of it is hit by a bullet resembles that in the case of the very brittle metal antimony, is actually a liquid. To show this, place leaden bullets upon a sheet of shoemaker's wax and then support the whole upon corks. At the end of a month the corks will be found floating upon the sheet of wax instead of beneath it and the bullets will be at the bottom as in a liquid.

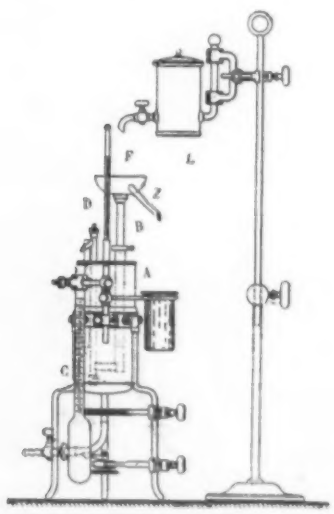


Fig. 3—Barbey ixometer with special receptacle for heating the oil

Georges Claude has employed the inertia of viscous bodies, which opposes rapid displacements, to construct an extremely light platform for trench guns. For this purpose a trough is dug in the ground and several liters of a mixture of resin and coal-tar are poured into it. At the bottom of the trough is a metal plate bearing the jointed gun barrel. The gun is therefore immersed to a certain height in the viscous mixture which does not prevent it from being moved for the purpose of taking aim, but which functions like a block of reinforced concrete at the time when the shot is fired, thus ensuring invariability of aim.

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT, from *La Nature* (Paris).

POISEUILLE'S EXPERIMENTS.

The first person to make precise measurements of the viscosity of liquids was Dr. Poiseuille. The remarkable memoir presented by him to the French Academy of Sciences was adjudged by that body worthy of being included in the Collection of Memoirs of Foreign Savants published by them, and was accompanied by the following words of appreciation:

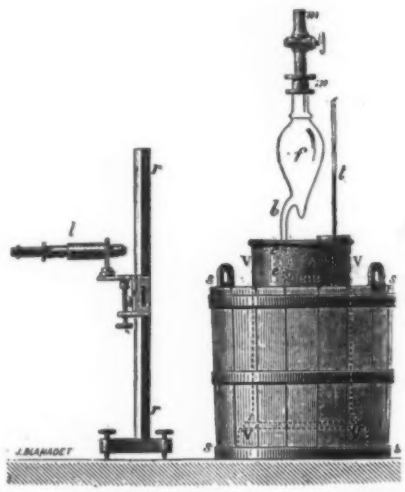


Fig. 1—Poiseuille's apparatus for determining viscosity

"M. Poiseuille includes a large number of experiments which were made by him with great care and with the employment of all the means of precision at the disposal of modern science. These experiments establish laws governing the flow of liquids in tubes of small diameter; several of these laws, it is true, had already been obtained by calculation, but had not hitherto been verified by experiments within sufficiently extensive limits."

Dr. Poiseuille made use of every possible precaution to avoid the principal cause of error, i. e. the flow by drops. As he observes, the affinity of the liquid for the matter of which the tube is composed causes it to adhere to the solid part of the section; it accumulates here and forms a drop which increases in size and finally falls. There results from this a backward reaction, a pressure at the orifice in the direction contrary to that of the flow which is accordingly continually being disturbed and is never uniform.

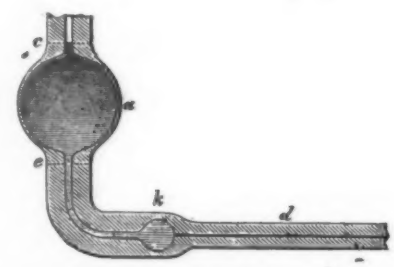


Fig. 2—Detail of Poiseuille's viscosimeter

Furthermore, Poiseuille filtered distilled water with the most scrupulous care in order to free it from all foreign corpuscles. He repeated this filtration a very great number of times, until when it was examined for transparency with the utmost care, it was impossible to detect the minutest body in suspension. This examination might be carried still further today by the employment of the ultramicroscope and it is probable that the twenty filtrations made by Poiseuille would be quite insufficient to obtain water which would appear pure when so examined. However, the dimensions of the corpuscles revealed by the ultramicroscope do not exert any great influence upon the viscosity. Poiseuille's viscosity apparatus was arranged as shown in Fig. 1. Through the capillary tube *d*, Fig. 2, which is completely immersed, he passed a given quantity of liquid at a given temperature and pressure, the liquid being measured between the marks *c* and *e* of a bulb *a* which is welded to the tube. The time required for the passage of the liquid for different pressures, and for different lengths and sections of the tube, was carefully noted. The pressure for producing the flow was furnished by compressed air, carefully regulated.

The swelling *k* limits with great exactitude the entry of the liquid into the capillary tube. Poiseuille's experiments proved that the volume of liquid, Q, traversing a capillary tube is, other things being equal, proportional to the pressure *P*, and the fourth power of the diameters, *D*, of the tube, and inversely proportional to the length, L, of the tube: $Q = K\frac{PD^4}{L}$

K is a constant which differs with each liquid and which increases rapidly with the temperature. Hot water is less viscous than cold water, and for this reason its cleansing power is greater.

According to Poiseuille's researches *absolute viscosity* *N* is expressed in dynes per square centimeter by the formula

$$N = \pi \frac{p}{8} \frac{r^4}{v\, l} t$$

One point remained doubtful: whether there is a complete adhesion between the liquid being tested and the capillary tube. Researches by Couette have definitely proved that the nature of the containing wall does not modify the viscosity of the liquid. The question had remained uncertain previous to these experiments. Coulomb proved by means of an oscillating disk that the results were the same whether the metal was naked, greased, or covered with sand. Poiseuille's experiments demonstrated further that there is a perfect adhesion between the water and the surface of the glass.

But Navier had supposed from *a priori* reasoning that the liquid was capable of sliding along the walls with a limited velocity, and was of the belief, consequently, that there resulted an amount of friction proportional to the said velocity. The experiments conducted by Girard, in fact, yielded coefficients of internal friction which were too low, which seems to indicate sliding. The experiments made by Von Piotrowski and interpreted by Helmholtz likewise appeared to reveal, though not very clearly, an influence exerted by the nature of the walls.

But the extremely precise experiments made by Couette have demonstrated that the supposed sliding does not occur. We will describe merely one of his qualitative experiments which can be readily repeated by anyone. The apparatus consists of a rather long capillary glass tube with a diameter of about half a millimeter welded to a bulb contained between two bench-marks. The time required for the flow of the water to take place is noted and the experiment is then repeated under exactly the same conditions except that the tube has been previously either greased, var-

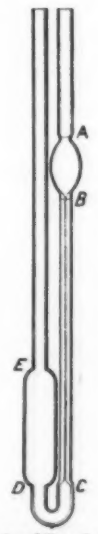


Fig. 4—Ostwald's viscosimeter

nished or silvered; the time required for the flow remains the same in all cases, except, of course, that the decrease in the diameter due to the grease, to the varnish, or to the silver must be taken into account. In the case of the last the diminution in size is so slight, because of the thinness of the layer of silver deposited, as to be practically negligible.

Ducleaux demonstrated that in the case of liquids there is an immobile layer which adheres to the wall. This can be shown by the following experiment. Into the upper part of a thermometer containing a column of colored alcohol, a drop of uncolored alcohol is introduced; it is then heated and at the instant that the colored alcohol reaches the uncolored layer it pierces it like a gimlet and spreads itself out upon the surface. Ducleaux measured the thickness of the adherent superficial layer and obtained the following results for the liquids named:

Liquids.	*Thickness in microns.*
Water	0.50
90 per cent alcohol	0.64
Ether	0.25
Olive oil	3.44
Glycerine	4.88

It follows that in the case of very narrow capillary spaces the influence of this immobile stratum may become appreciable. A much more serious cause of error is to be found in the influence exerted by the extremities of the tubes employed.

VISCOSIMETERS.

In practice viscosity is not measured by Poiseuille's method. Various instruments have been proposed for this purpose under the name of viscosimeters or ixometers. Each government has put its official stamp of approval on one or the other of these. Viscosimeters are so called because they measure, or are judged to measure, the degree of viscosity. Barbey's ixometer (see Fig. 3) measures fluidity, i. e. the opposite quality to viscosity.

The viscosimeters most frequently employed to examine lubricating oil are those of Redwood, of Engler, and of Saybolt, and the ixometer of Barbey.

The Redwood instrument has been adopted in England by the War Department, by the principal railroad companies, etc. It consists of a copper reservoir whose bottom is pierced by a capillary orifice. Immersed in this reservoir are a thermometer and a rod terminating in a ball which permits the operator to open and close the orifice at the bottom at will. The reservoir thus fitted is placed inside an envelope forming a thermostat. By means of a stirring implement and a thermometer, the temperature can be regulated and read. When the temperature at which the test is to be made is attained and remains constant, the stopper is lifted; the oil thereupon runs out and drops into a graduated vial having a capacity of 50 cubic centimeters and placed beneath the apparatus. The time required for the flow of this amount of oil is then carefully noted. In order that successive tests may furnish the same result, it is indispensable that the same quantity of oil shall always be employed and it is necessary to avoid any deformation of the capillary orifice in the construction of the apparatus. To this end the said orifice which is, of course, identical in all instruments, is made of agate.

Very similar in principle and enjoying as much favor in Germany as the Redwood instrument in England, is the Engler viscosimeter. It consists of a brass reservoir into which the oil to be studied is poured. To the inside walls there are fastened three markers arranged at the vertices of an equilateral triangle. These indicate the level to which the reservoir is to be filled, and when this level is reached the volume of the liquid contents is equal to 240 cubic centimeters. The cover of the brass reservoir is pierced in the center by a stopper made of hard wood in the form of a sharpened pencil. An orifice situated at one side allows the insertion of a thermometer. At the bottom of the reservoir is the tube through which the flow takes place; this tube, of a definite length and diameter, which are, of course, always the same in all apparatus of the same model, is not very long (length 20 mm., diameter above 2.90 mm., diameter below 2.80 mm.); the apparatus is standardized with the most scrupulous care by the Physikalische Reichsanstalt. The orifice is opened or closed by the wooden stopper. The reservoir is surrounded by either water or oil which is brought to the required temperature by means of a burner. The agitation is secured by means of an apparatus moved either by hand or by a motor. In the original form one might fear lest the burner might overheat the tube through which the flow takes place, but this is not the case. However, certain slight modifications have been made in the instrument. Furthermore, since it was not possible to employ it for the petroleum fractions, another viscosimeter especially designed to measure the viscosity of these substances was invented by Ubbelohde.

In the United States the Saybolt viscosimeter is employed. As in those described above, the copper reservoir for the oil is enclosed in a large water-bath. It is not made entirely of metal but has a glass window corresponding to a similar one in the water-bath. The oil to be tested is poured into the viscosimeter and in order to be sure of always operating upon the same volume there is a series of overflow holes, situated at suitable heights. After filling and equalizing the temperature the oil is allowed to flow out and at the same time a chronometer is started which is stopped as soon as the surface of the oil reaches the level opposite the eye-piece.

The Barbey ixometer, which is designed to measure the degree of fluidity, is very different. The principle of this apparatus consists in measuring the flow of a liquid, usually of a lubricating oil, under a nearly constant load—the difference between the levels of two overflows—under conditions in which the density of the various liquids examined occasions only a slight variation in traversing a capillary space obtained by placing an accurately calibrated steel rod inside a hollow brass cylinder which is likewise accurately calibrated.

Fig. 3 represents the ixometer provided with a supplementary reservoir *L*, which permits the previous heating of the liquid in order to make sure that it will be of the exact temperature indicated by the thermometer immersed in the water bath *A*. The liquid runs from the receptacle *L* into a cup-shaped funnel *F* having connected with it at one side the overflow tube *Z*. The funnel *F* surmounts the ixometer proper which consists of the large tube *B* which is vertical and is connected in its lower portion with a horizontal tube *C* which forms a right angle with the vertical tube *B* and with the vertical tube *D*. In the latter a precisely calibrated capillary space is made in the following manner: The tube *D* has a bore of 5 mm. and is closed at the bottom by a stopper. In the center of this stopper is a small conical orifice designed to receive the point of a steel rod which is kept in place by the aid of another stopper situated in the upper portion. Upon this stopper and upon the plane extremity of the steel rod are two bench marks which must be made to coincide. The tube *D* has a spout at one side through which the oil flows out. The difference between the two overflows is the load or pressure under which the flow of the oil takes place. When the apparatus is properly regulated and the flow of the oil regular, one of a series of graduated tubes is placed beneath the spout, being chosen according to the degree of fluidity of the oil; a chronometer marking sconds is started at the same time.

None of these apparatuses measures the absolute viscosity, but while the fluidity indicated by the Barbey ixometer approximates with sufficient accuracy, so far as regards the factor of *density*, to the inverse of absolute viscosity, at least within the limits within which the apparatus functions well, the same thing cannot be said of the Engler viscosimeter and the instruments derived from it.

In a recent communication entitled "Contribution to the Study of Viscosity," Messrs. Georges Baume and Paul Nicolardot have called attention to the following facts which are truly extraordinary from the point of view of scientific exactitude and honesty. The indications obtained from the Engler viscosimeter have no simple relation, actually, with the absolute viscosity, and the inventor of the apparatus was well aware of this.

In spite of the attempt of M. Ubbelohde to find a relation between the indication of the Engler viscosimeter and the absolute viscosity, the formula which he proposes:

$$Z = S\left(4.072\,E - \frac{3.513}{E}\right)$$

in which Z equals the viscosity, S the density and E the Engler reading, provides but an imperfect correction. Better still, since he here had a viscosimeter giving some sort of indications for oils, M. Ubbelohde constructed another which is likewise far from precise for petroleums, as we have seen. Both these are endorsed by the Physikalische Reichsanstalt, and only failed to be adopted by the International Petroleum Congress at Vienna in 1912, by the intervention of MM. Guiselin and Nicolardot.

There are still other methods of measuring viscosity, such as the vibration of a pendulum or of a disk, or the fall of a ball; but the simplest of all apparatuses is incontestably that of Ostwald. It consists essentially of a U-tube (Fig. 4) one of whose limbs includes a small ball of 2 cu. cm. capacity. The two reference marks *A*, *B*, are placed above and below the ball respectively. Below the ball is the capillary *B*—*C*. The ensemble constituted forms the first branch of the U-tube. The capillary tube, whether or not welded to a larger tube is connected with the cylindrical reservoir *ED*, which in its turn is surmounted by a straight tube. This viscosimeter may be easily placed in a thermostat. It always contains the same volume of oil. The temperature is kept strictly constant by employing either liquids boiling under a constant pressure or refrigerating mixtures of constant freezing points. By the aid of an aspiration or by compression the oil is brought up *above* the upper reference mark *A*. The liquid is then allowed to flow out and as soon as it reaches the level of the bench mark a chronometer marking seconds is set in action.

The Ostwald viscosimeter permits the measurement of comparative viscosity; it needs only to be standardized with pure water in order to determine the constant of the instrument and consequently to know the absolute viscosity.

According to the opinion which is generally accepted since the researches of Hirn, the viscosity of lubricating oils affords a measure of their lubricating value. It must be remarked, however, that in practice empirical tests often furnish the best guidance.

Cloud Negatives

IT is not a good practice to start out with the intention of making cloud exposure exclusively, as this tends to securing a number of negatives of very much the same character. It is better when out on other work to devote a plate or two to any particularly good cloud effect, and to make a note which can be transferred to the bottom edge of the plate as to the point of the compass at which the camera was pointing and the time of day when the exposure was made. Although it is possible occasionally to obtain good results on an ordinary plate without a yellow screen, it is much easier to do so with an orthochromatic plate and a proper filter. There is really no reason why the landscape photographer should ever expose an ordinary plate and many reasons why he should use color-sensitive ones. It is a mistake to use too dark a color screen for sky work, the *K2* strength being quite sufficient to give the proper contrast. If a deeper color be used the blue portions will come out practically black and the sky will look too heavy for the view. In our idea most sky negatives are too thin, as this adds considerably to the difficulty in printing them to the proper depth to suit the subject, particularly when enlarging or printing upon bromide paper. This often leads to an unnatural appearance in the finished print and causes some people to contend that a perfect result can only be obtained when the clouds are secured upon the same plate as the view. The real reason for this is that in this case the clouds have received full development, which can also be given with a properly screened plate. We may perhaps be allowed to remind those who are not experienced in this class of photography that it is always desirable to include a narrow strip of landscape below the clouds, so that the negative may not be used upside down. This has the additional advantage of preventing the camera being pointed to the zenith and the resulting clouds printed in near the horizon, a fault which has often been committed.—*British Jour. Photog.*

A few pages farther on another writer in the same journal writes as follows in the course of an article on "Local Views as Postcards" (italics are ours):

"Another improvement I would advocate is in the matter of skies. Here perhaps the improvement may add a trifle to the cost of production, but a trifle which will be amply repaid by the improvement in the resulting prints, and consequently an improvement in their popularity. The terribly crude white skies which almost everywhere obtain must be an eyesore to the person with any art education, and when it is remembered that a dead-white is not a correct rendering of even a clear and cloudless blue sky, it will be seen that the photographer who wishes to improve his work, and incidentally his output, has here scope for a very material improvement. A grey sky (printed through) is almost as bad as a dead-white, and the alternative presents itself of introducing *artificial clouds*, or, at any rate, *clouds by artificial means*."

The Editor would here register a protest against the practice, perhaps no longer so general as it once was, of introducing or printing in "skies," i. e. clouds from

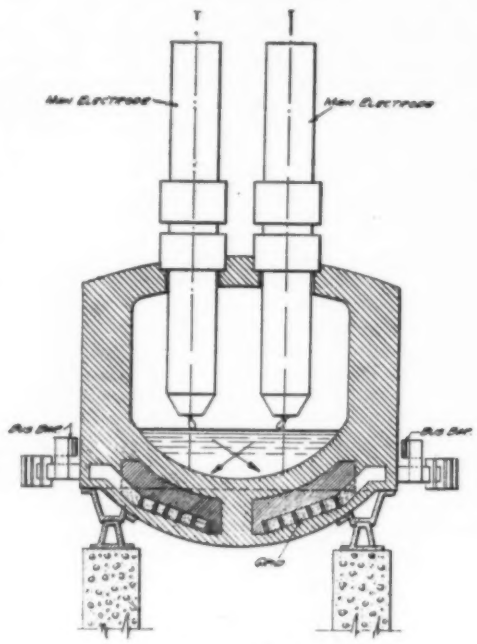
(*Continued on page 144*)

The Electric Furnace—I

A Survey of Its Development, Its Scope and Its Future

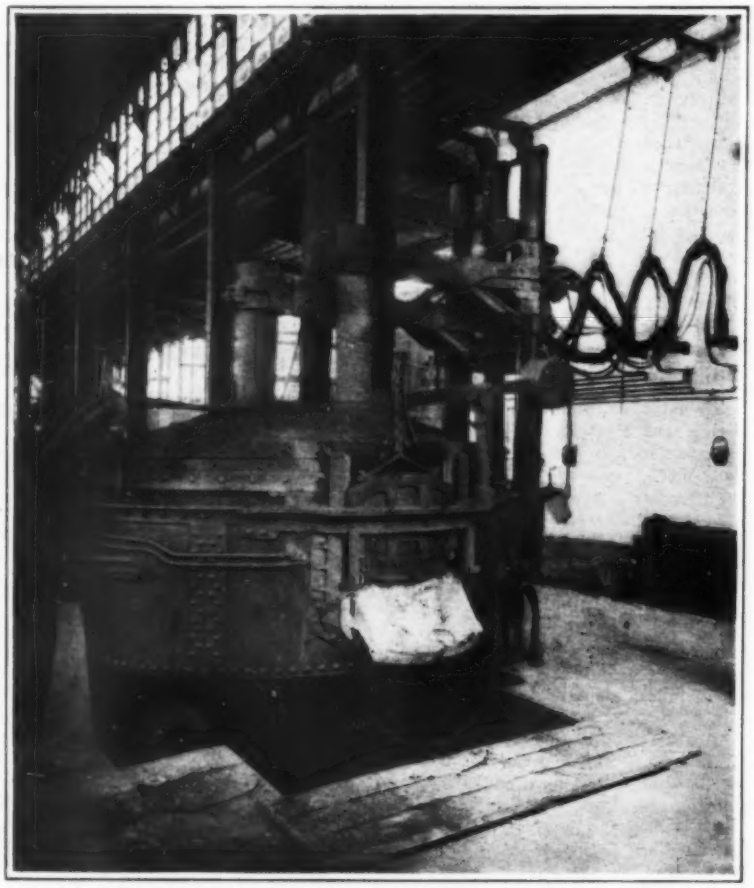
By F. Rowlinson*

THE development of electro-thermic methods for the production of metals, alloys and refractories is of very recent date. Although Siemens, Heroult, Hall, Stassans and Acheson had conducted experiments upon a commercial scale prior to 1900, most of the real progress of the electric furnace has taken place since this date. Today almost all ferro alloys are made by electrical methods and the world's output of electrical steel is growing at a phenomenal rate. Work in non-ferrous metals has not progressed with the same rapidity, but there is a growing spirit of research among the smelters of non-ferrous metals which promises fair to call electro-thermic methods to its aid. With the increasing demand for graphite (in itself caused very largely by the development of the electric furnace), for abrasives (due to revolutionized machine shop methods) and for refractories, furnaces of the resistance type have come into use. There now seems every possibility of electro-thermic methods taking a great place of their own among the industries of the world, if not ousting entirely less efficient time-honored practices. The application of electricity to heating problems requiring thermic intensity as distinct from, or in addition to mere calorific efficiency, has made possible developments which are unattainable by the use of combustion furnaces. This point must be emphasized from the first—that the electric furnace not only to some extent supersedes the combustion furnace, but occupies a sphere of utility peculiarly and unassailably its own.



TRANSVERSE SECTION

The peculiar advantages which electricity possesses as a means of producing high temperatures are now well enough recognized. Chief of these is, of course, the fact that electricity secures the maximum energy concentration at one point, that where the heat is required. This property of internal heating is not possessed by any combustion furnace save the blast furnace, which is admittedly the most efficient method of utilizing fuel energy. This essential property brings in its train another important result contributary to the success of the electric furnace—that, in many cases, the furnace walls may themselves be composed of the materials to be treated, and in all cases the refractories composing the furnace are not subjected to the same wear and tear as they would if the same degree of temperature had to be attained in the combustion furnace. Further, there are no products of combustion to be taken care of, nor does the application of electrical heating, as a rule introduce any deleterious element into the final product, although in the application of electricity to copper smelting the electrodes sometimes produce contamination by iron, etc. Moreover a combustion furnace, to attain its maximum efficiency, must either carry out the process under oxidizing conditions, which is often not desirable, or recourse must be had (as in crucible smelting) to the external application of heat to an inner closed chamber. This latter course immediately introduces sources of trouble and loss, not only by the provision of suitable refractories, but also by the unavoidable temperature loss by transfer through the walls of the inner chamber. In electrical high temperature work the atmosphere may be varied at will from oxidizing, through neutral to strongly reducing. Electrical energy, too, may be conveyed great distances at small cost—fuel can only be profitably utilized in large quantities near its sources. In general, the electric furnace is indispensable where the temperature to be attained exceeds 2,000°C. The limiting factor to the use of electricity for high temperature work is an external one only—the difficulty of finding refractory materials which will stand the severity of the treatment. For work at less than 1,500° local conditions come into play, making the suitability of the electric furnace a matter requiring careful weighing—but even under these circumstances, in cases where uniformity and purity of product, ease of regulation, or high efficiency are essential, the electric furnace will take precedence. It is the present purpose to show how the peculiar advantages and properties of electro-thermic methods have up to the present succeeded in establishing the electric furnace on a commercial basis, and to indicate the directions in which progress is most likely to take place.



An American furnace invented by two Chicago engineers. It has 1, 2 or 3 electrodes, the 1-ton unit using one electrode, and is circular in shape. About 11 such funaces are in use in the United States

The industry which, beyond all others, requires the use not only of high temperatures, but of high temperatures generated on a gigantic scale, is the iron and steel industry. It is difficult accurately to forecast the future rôle of the electric furnace in the metallurgy of iron and steel. Twenty years ago Heroult dreamed of the supremacy of electro-metallurgy in the world of iron and steel. How far his dreams have been realized may be understood from the following statistics: In 1909, the figures (then published for the first time by the American Iron and Steel Institute) for the production of electric steel in the United States, were 13,762 tons; in 1917 this had risen to almost a quarter million tons. Progress in the electric smelting of iron ores has not been nearly so great. The reason is not far to seek. The blast furnace alone among combustion furnaces has an extremely high efficiency—for the same reason that the electric furnace is highly efficient—namely that that heat is set free internally and where it is most wanted, in direct contact with the material to be reduced. So that in most cases the application of electric smelting to iron ore reduction is ruled out from the beginning. It is only in cases where otherwise valuable ore deposits are situated in a district so remote from fuel sources that the transportation of either the fuel or the ore is financially impossible that electric smelting has made headway. This is so in Scandinavia and in California, and to a smaller extent in Italy and Spain.

One point must be noted with regard to the reducing agent used in iron smelting by electric means. Charcoal has been found eminently satisfactory, but its use would lead to a wholesale depletion of valuable forest areas. Coke has been used as a substitute, but general opinion seems unfavorable, since its use is attended by increased power and electrode consumption, which more than balance any advantage derived from its comparative cheapness. In the West Coast States the problem is attracting much attention. Charcoal is expensive, and future supplies exceedingly precarious; so suitable coking coals are found near enough to be of service. On the other hand there are abundant supplies of crude mineral oil in the neighborhood, and there is no doubt that this would satisfactorily perform the reduction, were a type of furnace to be developed for its use. This problem once solved, there opens a broader field for the production of electrically smelted iron. Indeed, with both the reducing agent and the heating agent under such exact control as is possible with oil and electricity, there should be some possibility of the electric production of steel direct from the ore. Under these circumstances, and granting the availability of cheap hydro-electric power, the smelting of iron ore may be commercially profitable. There is some future scope, therefore, for countries possessing poor fuel resources, but with electrical power procurable at a cheap rate to develop the electric "blast" furnace. As regards the great iron-producing countries, the possibility of future progress in this direction can be safely described as "nil."

The future of the electric furnace in the steel industry is very bright indeed. The world's demand for steel is continually increasing, not only as regards quantity, but also as regards quality. The consumer continually demands more service from the same bulk of material. The consequence of this is an increasing spirit of emulation between steel makers. As wrought iron was superseded by Bessemer steel on account of the latter's superiority and relative cheapness, so Bessemer steel is largely being displaced by open hearth steel. The predominance of the Bessemer steel and rolled sections long ago gave place to the more enduring reliability of open hearth steel. The Bessemer rail, though still having a powerful hold on the market, is yielding to the product of the open hearth process. Quality now stands above mere quantity. There was a time when tonnage alone was the chief thing; neither the maker nor consumer bothered much about the quality providing that it was passably good. But the advent of alloy steels has changed all that. Quality now takes first place, and although tonnage still continues to grow, it has taken, relatively, a secondary position. This has a great bearing on the

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future development of the electric steels.

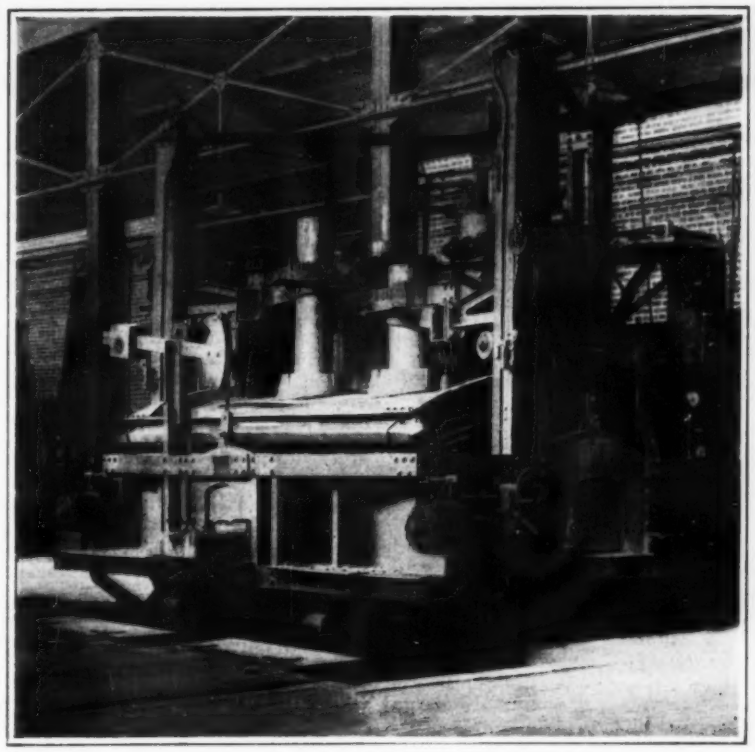
The first use of the electric steel furnace was almost solely confined to the working up of poor quality scrap into high class steel—usually alloy steel. The process, metallurgically speaking, is intricate and not particularly economical. In the first place, electricity is not an economical preheating agent—its efficiency is most pronounced at temperatures exceeding the melting point of steel. Further, the character of the chemical reactions during the melting-down and refining of low-grade scrap is such as to render necessary two, and sometimes three, entirely different slag reactions. This in turn necessitates the removal of the first slags and their replacement by others of a different character. Simple though the process may seem to the layman, it requires far more metallurgical skill and unremitting care to produce satisfactory steel from the low-grade scrap by the use of several slags than to carry out the process in separate furnaces, each performing a simple function, and each carrying a single slag. These considerations have brought about the introduction of the so-called duplex and triplex electric processes. In these the employment of the electric furnace is of a refining rather than a purifying nature.

The duplex process takes pig-metal, heavily charged with impurities, from the blast furnace via the mixer, and effects a preliminary purification under a highly basic oxidizing slag. By this means practically all silicon, manganese and carbon, and most of the phosphorus are cleaned from the metal, either in the Bessemer or open hearth furnace. The metal is then turned into a ladle and nozzle-poured into a second ladle, so as to eliminate totally the first oxidizing slag. The metal is now in a super-oxygenated condition, and would be useless for ingot pouring unless it were killed by the very liberal use of deoxidizing alloys. It is to conserve the latter, to further refine the steel, and to bring it into that "dead melted" condition so sought after by the manufacturers of crucible steel, that the electric furnace is used. The metal from the ladle is poured into the electric furnace and a highly basic *reducing* slag added. The super-oxygenated metal is rapidly brought to a fit condition both as regards slag reactions and temperature to give a metal perfectly quiet in the ladle and the molds. Electric steel is almost free from occluded gases (which give rise to blow holes and similar defects); it is exceedingly ductile in comparison with similar steels made by other processes, and it will stand the most severe mechanical, physical and chemical tests. The duplex process has further been simplified into the triplex process in which the steel is successively treated in the Bessemer converter, the open hearth furnace, with a final refining in the electric furnace.

So much for the manufacture of electric steels—the lines along which progress will take place in this direction seem to be quite clear. Increasing quality will beget increasing production, and this in its turn will demand a minimum manufacturing cost. The tendency in electric steel practice is continually toward larger furnaces, although not to the same extent as with open hearth furnaces. It is perhaps looking too far into the future to predict the general usage of electric furnaces of above 30 tons capacity (indeed many state this to be the economical limit of size, since the power losses between the transformers and the furnace then assume difficult proportions) but there seems to be no real reason why large furnaces should not ultimately be the rule. In consideration of the economies in working that have taken place during the last twenty-five years of open hearth practice, it would appear reasonable to expect similar improvements in the design and performance of electric steel furnaces. Surely it is realized by our steel makers that the highest quality and large tonnage are not incompatible?

The future field of electric steel seems to lie in two directions. Alloy steels, more particularly those containing easily oxidizable elements such as vanadium, chromium, silicon, and manganese, and steels with large percentages of refractory alloying elements (as high speed and magnet steels) will certainly be products of the electric furnace. There is an important saving in alloy additions when electric furnaces are used in steel making—a factor of much account in these present days of scarcity in many ferro-alloys. Progress may possibly be made in the production of alloy steels direct from the pig metal. This applies more particularly to nickel-bearing alloys. In Canada there would seem to be a great future for a directly-produced nickel-copper steel having mechanical properties very similar to nickel steels, but being chemically highly resistant to corrosion. This class of steel, the author ventures to predict, will play an important part in the shipbuilding of the future.

The peculiar property, only recently emphasized, which electric steels possess of not losing their characteristic ductility at low temperatures to anything like the same extent as ordinary steels would seem to be of use in aircraft and railroad work. Indeed, with the rapid increase in railroad loads, already enormous, there seems to be a great future in electric steel in a direction at one time quite monopolized, and even now large dominated by Bessemer steel.



A British electric furnace of oblong shape with 2 or 3 electrodes arranged in a row. The steel is poured from the top hole at the side. About 11 are also in operation in United States

FERRO-ALLOYS AND THE ELECTRIC FURNACE.

It was not until 1899 that ferro-alloys came to be made commercially by electric furnaces. Until that time they had been chiefly a product of the blast furnace, and their number was practically confined to ferro-manganese, low-grade ferro-silicon and ferro-chrome. The type of furnace originally employed has been little changed—the Siemens' type having a conducting hearth of carbon, dolomite and magnesite, or, in the case of low-carbon ferro-chrome, chromite, and one or more upper electrodes still predominating. The furnaces are usually open-topped, and there is no necessity for a shaft, since, contrary to the practice in iron-ore reduction, the reaction is chiefly with solid carbon. The chief difficulties at first encountered, that of excessive volatilization loses in making ferro-manganese, and that of high carbon content in ferro-chrome, have now been overcome. The difficulties which survive are mechanical and electrical rather than metallurgical.

The electro-thermic manufacture of ferro-alloys has progressed more rapidly in Europe than in the United States. The reasons are not far to seek. Hydroelectric power is there cheaper and more favorably situated, both with regard to the raw materials and the market. The result is that many of the ferro-alloys used in this country are imported, and this is the reason of the shortage we are now experiencing. In ferro-vanadium, ferro-titanium and ferro-chrome we about hold our own, but in ferro-manganese and ferro-silicon there is a considerable deficiency between home supply and demand. With the increasing development in the use of electric ferro-alloy furnaces, this deficiency should not be of long standing.

There is considerable scope for economy in the operation of electric ferro-alloy furnaces. With the present demand for their products, this point has been somewhat overlooked, but the time is not far distant when competition will be exceedingly keen both as regards price and quality. As has been said, these furnaces are usually open-topped, resulting in very considerable loss of heat, both by radiation and by carbon monoxide escaping and burning to waste. Intermittently-worked furnaces producing ferro-tungsten and ferro-vanadium, etc., may be satisfactory on this basis, for the high price of the product allows considerable latitude for loss. But with furnaces manufacturing ferro-silicon and ferro-chrome there seems to be a tendency toward the adoption of closed tops and feeding shafts, in which the charge is preheated with advantage to the cost and convenience of working the furnace.

There does not seem any great prospect for future development, other than in output, taking place in the application of the electric furnace to ferro-alloy manufacture. There have been very extensive researches into the effects of alloying elements in steel within recent years, and from the results of these it does not seem likely that any steel alloys will be discovered in the future which will revolutionize ferro-alloy manufacture. Experiments in the denitrification of steel have indicated that ferro-zirconium is likely to be of use for this purpose, and it may be expected that the manufacture of this allow will be proceeded with commercially. The metallurgical problems involved are, however, rather different from those usually met with in ferro-alloy practice. There seems, too, to be a small field for the manufacture of pyrophoric alloys such as ferro-cerium, used in igniters for miners' lamps and for similar purposes, but the whole demand for this class of alloy will not be great.

The application of the electric furnace to non-ferrous metallurgy has not advanced with the same rapidity as in the case of steel. This is no doubt due to the fact that temperatures in non-ferrous work do not ordinarily rule as high as in ferrous metallurgy. None the less progress is being made, and will be discussed in the sequel.

River Bends and Meanders*

Mechanical Analysis of the Forces at Work Suggests That Meanders Result from "Buckling"

By Colonel Hoc

THE very remarkable tendency exhibited by water courses to assume in certain cases a sinuous form—a form often repeated quite rhythmically—seems not to have been studied so thoroughly as it deserves to be. The explanations given of this "serpentine" motion in technical works are still both inexact and incomplete. They are often referred merely to the inequality of resistance in the bed of the stream and to the reflection of the current from one bank of the stream towards the other. However, it may be pointed out that the phenomenon often occurs on the one hand in territory of the most regular character, and on the other that it may be observed in low lying gravel-covered areas whose tendency is to check transverse speed far more than to deflect it in its full force.

It is pointed out, also, that wherever there is even a slight concavity in one bank of a stream centrifugal force comes into play; the liquid mass rushes thither causing a raising of the level and a consequent formation of eddies which possess a very considerable degree of erosive power. But this explanation, however accurate it may be in many cases, does not indicate why the tendency to serpentine motion is so variable, sometimes exhibiting a maximum amount in placid streams and again failing to appear in those of swift current. Furthermore, close observation reveals many instances in which it is the convex bank which is eroded, in which case the stream tends to straighten its bed instead of curving it in the direction in which the centrifugal force is exerted.

Finally, the phenomenon is sometimes based upon

Fig. 1—Composition of forces acting when a railway car "buckles"

the deposits of gravel and sand made by streams, but these considerations are applicable only in certain cases.

The phenomenon of "buckling" is well known. Every body having one of its dimensions greater than the other is in unstable equilibrium when subjected to external forces exerted along the preponderating dimension, and in such a case every transverse curvature exhibits a tendency to be accentuated. A post which supports a ceiling tends to warp in the horizontal direction, and the arch of a bridge tends to warp in a direction perpendicular to its plane. As soon as the two forces of compression *F F'* (Fig. 1) undergo any accidental deviation with respect to the axis, they give rise to a transverse component, and the greater the absolute value of the two forces, the greater the value of this component.

But the theory of buckling is applicable to a mobile system, as we shall see further on. To simplify the matter let us first consider a system which is less complex than that of the liquid current; e. g., a train made up of cars of the same type drawn down a long incline by the force of gravity in a straight line. If the degree of inclination of the slope is constant and likewise the resistance to the motion, then all the cars will have the same normal speed, neither compression nor tension being perceptible in the couplings. But

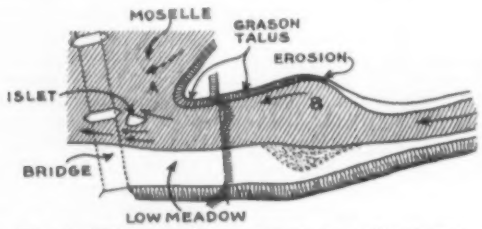


Fig. 2—Effect of high water at A on the course of the tributary B

if the speed of the lower cars tends to diminish either because their resistance is augmented by means of the brakes or because they have reached a less inclined slope, it is obvious that the couplings would be compressed. It is equally obvious that this compression would facilitate any transverse displacement which might tend to be produced accidentally either

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *Le Génie Civil* (Paris).

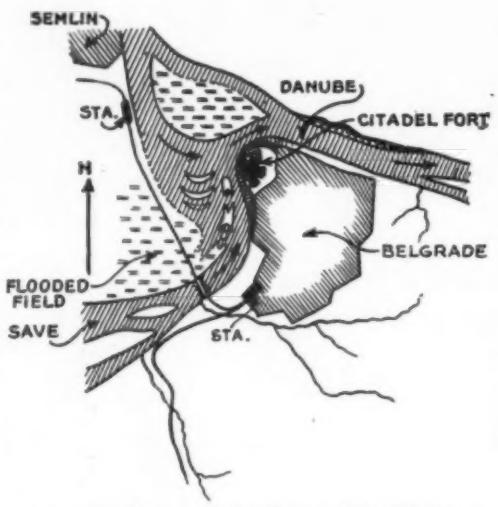


Fig. 3—Confluence of the Save and the Danube—contracted waterway and voluminous affluent

within the limits of the play of the wheels or by the spreading of the tracks. Here we see clearly that just as in the case of a flexible bar compression would tend to produce undulation or buckling.

If, on the other hand, the speed of the lower cars tended to increase either because of diminished resistance or because of an increase in the slope, the couplings would be subjected to tension; in this case the transverse strain would no longer tend to augment any existing or commencing curvature, but would tend on the contrary to straighten the train by dragging it towards the short radius.

The two phenomena exhibited by liquid currents are as follows, according to the circumstances:

(*a*) A tendency to bend inwards through the erosion of one of the banks, when the velocity of the current decreases by reason of an increase in the resistance of the bed of the stream, from alteration in width of the waterway or from decrease in the grade. If the curvature of the banks already exists this action will tend to augment it by reason of the superposed centrifugal force.

(*b*) A tendency to straighten out by eroding the convex bank (that of short radius), when from opposite causes the current is accelerated.

When threads of rain water run down the surface of a slightly oily pane of glass such as the window of a car, we constantly see them leave the vertical direction and form an abrupt curve, which is, however promptly straightened out. This phenomenon is the simplest form of the one described above. The thread of water being slowed up at one point by some resistance undergoes in its downward path the transverse inflection of a compressed rod.

If we turn now to the case of a river we find above bridges and sand-banks a strong tendency to inflection as is indicated in Figs. 2, 3, 4 and 5.

Fig. 2 represents a canal which is tributary to the Moselle at Toul at a period when the water in the latter is at a medium height. The high level of the river creates a resistance to the flow of the canal whose water-way is carried forward from its habitual emplacement *A* to below the pillar of the bridge. At *B* we can readily observe the inflection of the current with the erosion of the bank referred to above.

Fig. 3 represents the confluence of the Danube and the Save at Belgrade as it looked in July, 1914. At the foot of the rock upon which the citadel stands, the mass of the Danube hurls itself against the double obstacle of a contracted water-way and of a voluminous affluent. The observer obtains a definite impression that if this mass is inflected it is because of the said resistance and for no other reason. The crescent-shaped alluvial deposits which separate the various arms have too slight a relief and are too mobile to lend themselves to the usual explanations by reflections, etc.

Fig. 4 is taken from the Inn River in the vicinity of St. Moritz. Fig. 5 represents the strongly marked curve formed by erosion in the left bank of the Durance above the Brillanne-Oraison bridge. It exhibits the traces of an analogous curve upon the right bank. Similar erosions are repeated above several other bridges over the same river.

It is doubtless true in these last two cases that the obstruction of the bed by banks of gravel deposited in the retarded water above the obstacle help to throw the current toward the banks. This is a cause which exerts its influence in the same manner as the tendency to buckling. It even acts alone in times of low water when the depths are slight and when the pressures count for little by the side of the other forces present, in a current with a steep declivity. But this obstruction is not sufficient to explain an incurved winding of more than 180°, like that in Fig. 5.

If there remained any doubt that something more than the deposit of gravel is required to explain the phenomenon the example of the glaciers cited below would remove all uncertainty in this respect.

It appears to be true, therefore, in general, of a stream of water as well as for a train of cars, that a local resistance determines up-stream a tendency to lateral inflection, i. e. to winding, because of the compression between the said resistance and the force of the up-stream inertia.

In the course of a tranquil stream this cause acts alone at the beginning, but is reinforced by centrifugal force as soon as the first curvature has occurred. In the course of a rapid stream it is also reinforced

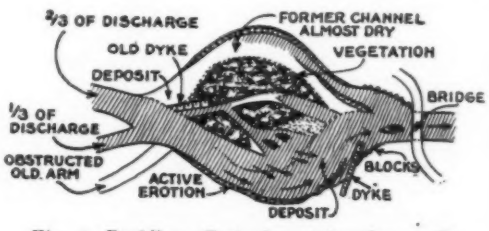


Fig. 4—Buckling effect of a contraction at the bridge (Inn at St. Moritz)

by the obstruction of the bed which results from the deposition of gravel above the obstacle.

Let us now imagine for a moment a water-course which is rectilinear and with a constant degree of fall running over a bottom which is capable of being undermined. It would be impossible for the dragging of the materials of the bottom to be uniform at all points. Certain portions would be excavated and others would fill up according to their comparative solidity and because of accidental inequalities of speed. After the lapse of a certain period of time the bed would exhibit a succession of troughs and crests. Each bank would form an obstacle in the sense of the preceding discussion and would create a tendency to transverse deviation in the area above, namely that of the trough. The longitudinal profile and the plan would then resemble more or less closely the diagrammatic forms shown in Fig. 6.

Everything would concur in accentuating these forms.

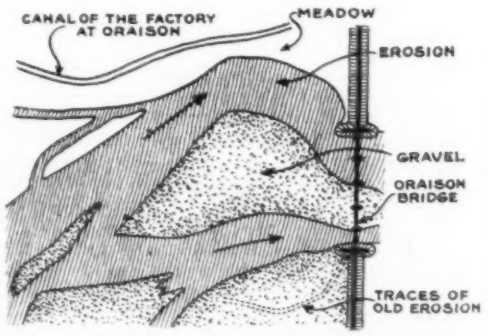


Fig. 5—Another meander due to grading above a bridge (the Durance at Brillane-Oraison bridge)

It is a well known fact that the transportation of materials by streams is particularly favored by eddies, which are especially apt to form in the curves (where the liquid streamlets have unequal rates of speed) and near shored up banks. The excavation would therefore increase both in width and in depth toward the concave bank of the curve, under the simultaneous effects of the transverse component shown in Fig. 1.

of the eddies, of centrifugal force, and finally, of the contraction of the bed by means of the deposits against the convex bank (see Fig. 8); at the same time the deposits would be increased upon the crests, where these causes would cease to operate.

We can easily imagine the regularity of aspect that would be assumed by such an ensemble in the bottom of a homogeneous valley in which the débris banks would be distributed at more or less constant distances according to the circumstances which condition the transportation so that the windings would assume uniform curvature.

In other cases the said gravel banks would be occasioned by deposits from affluent stream and would consequently be more irregular. This is doubtless what took place in the Theiss River already alluded to in reference to windings, since the course it traverses is

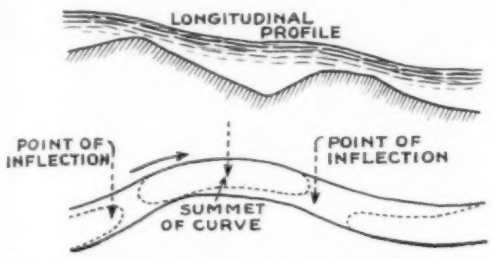


Fig. 6—Diagrams of points of cutting and depositing. Dotted lines are isobaths

more than twice as long as its length as the crow flies. The Theiss receives a series of tributaries coming from the Carpathian mountains and bringing with them such large quantities of alluvial deposits that it has displaced its bed a hundred kilometers towards the west since the beginning of the geologic era. It is very probable that the said alluvial deposits have been the cause of such an exceptional development of sinuosity by reason of the obstacles which they have put in the way of the current.

At first glance one is tempted to seek an explanation of the windings which characterize the Seine below Paris in similar declivities or obstacles. But this is incorrect. These windings are not of recent formation but fall into the category of what geographers term incised meanders, or those which are ancient in contrast to the modern ones which are known as divigent meanders. The Seine had as its precursor a river without any perceptible fall, through which the waters of the ancient lake of Beauce emptied themselves, describing meanders upon the surface of the tertiary massif around a middle northwest direction. But the bottom of the lake became progressively higher in its northwest portion, attaining an altitude of 260 meters in the forest of Villers-Cotterets, and 150 meters in Normandy. The water courses already formed between the Oise and the Yonne are obliged to make their beds descend through the sinuous *massif* in proportion as its relief is accentuated.

This condition is frequently met with (as in the Meuse below Charleville, etc.), and imparts difficulty to the apparently easy study by means of maps of the circumstances connected with the formation of meanders.

Various laws to which meanders are subject, especially as regards navigation, such as the relations between the outline and the depth, stability, and so forth, have been formulated by MM. Fargue and Girardon. They are closely related to the subject here treated, and would deserve to be quoted in their entirety, but that they can be found in all treatises upon applied hydraulics, we shall merely recall the importance of a gradual and successive variation of the curvature for the production of a regular and stable profile along the *thalweg*.

M. Clavel has pointed out, elsewhere, in a certain section of the Garonne, a regular displacement of the meanders, in the course of time, in the down-stream direction (Fig. 7). He explains this fact by the observation that the corrasion is greatest as the greatest depth; but, according to one of the laws of Fargue this is always at some distance down stream from the apex of the concave curve. The attack on the banks progresses down stream, therefore, along the axis of the *ensemble* of the valley. It would be interesting to ascertain whether this phenomenon is general—that is, of course, when the banks present no fixed point.

Let us make now a final observation with respect to successive meanders, which has the advantage of being entirely detached from the questions of rapidity and of gravel deposits which complicate the subject in the case of water courses. We would speak of glaciers, those slow-moving rivers of ice whose flow presents so many curious analogies with that of streams of water.

Tyndall pointed out that in glaciers the thread of the current is displaced alternately to the right and to the left of the median line, forming approximate loops which succeed each other, now on one side and now on the other. In other words, the mass tends to be borne toward the outside of each curve, and we are

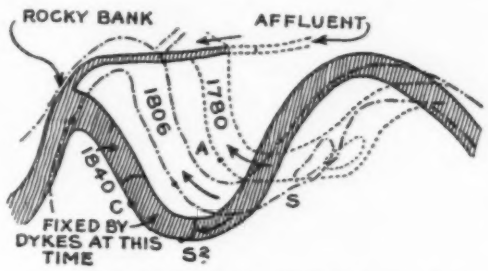


Fig. 7—Systematic down-stream shifting of a meander in the Garonne

able to recognize the phenomenon of buckling, though there can be no question here of a reflection of the current or of the operation of centrifugal force since the speed of flow is imperceptible.

Let us now examine cases analogous to that of the train of cars with a constantly increasing speed, it being understood of course that in a water course the traction is replaced by a tumultuously flowing current.

Fig. 8 was taken from the Moselle, between Thaon and Girmont, shortly after a rise in the river. The current follows, as is usual, the foot of the concave bank with steep slopes. But we observe, opposite the convex bank a trough *DC*, excavated in the deposits of gravel *ABC*, such as is ordinarily found at low water. We are accordingly obliged to conclude that during the rise of the waters the principal current was carried to this side, approaching a straight line as nearly as possible. If the rise of the waters had lasted long enough the gravel deposit would undoubtedly have been entirely excavated; the excavation began along the line of trough close to the resisting border, by reason of the phenomenon referred to above, namely the formation of eddies against the solid banks.

Similar instances of the deflection of the main current and of the straightening out of curves during a period of rising waters occur quite frequently. The comparative importance of the obstacles is modified, in fact, by the increase in the height of the water and in its rapidity of flow, and some of them are overcome by the kinetic force without an increase in the static pressure above them being required, as before. The influence of these obstacles upon the curvature of the current is consequently greatly reduced.

The formation of a great many islands, e. g. those in the Seine below Paris (Billancourt, etc.), can be explained by these returns of the main current towards the interior side in periods of rising waters, with the excavation of troughs like *DC* in Fig. 8.

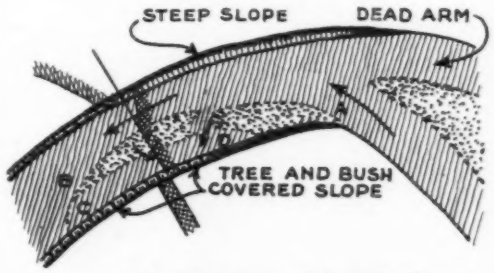


Fig. 8—The Moselle between Thaon and Gismont. Effect of high water currents

In streams of very steep grades the formation of meanders due to "buckling" is hardly ever exhibited except at moderate stages. During periods of low water the current rambles through a bed much too wide for it and is obstructed by deposits of gravel left by the last period of high water. It winds its way among troughs excavated by these rising waters opposite the banks, and it is deflected most of all by the accumulations in its bed.

[The second part of Colonel Hoc's article is largely occupied with a theoretical study of the meanderings of rivers, executed by means of mathematical calculations, and consists mainly of the study of elastic stability, particularly the phenomenon known as buckling. Buckling may be described as mechanical instability of the apparent form with a tendency to increase of all transverse incurvation. An example of this is the tendency to flexion of a rubber pipe traversed by water under pressure. Another example is the tendency to assume a meandering or serpentine form exhibited by rivers when their banks are capable of being deformed by erosion. If there are fixed points which may be represented by piles, rocks, etc., the water course is comparable to a bar of metal two points of which are held fast transversely, with the peculiarity that theoretically there is no minimum distance below which the buckling will cease, since the formula of Euler is not applicable, the constant elasticity being nil. In practice the river bed remains sufficiently rectilinear if the fixed points are near enough to each other. If there are no fixed points, which indeed is the most usual case, the importance of the action upon the banks of the river will depend upon the variation of the pressure and we can determine by calculation the various positions of equilibrium assumed by a rod of indefinite length when the pressure is constant, when the pressure is maximum at a given point, and when the pressure is minimum at the said point.

The calculations in question were made at Colonel Hoc's request by Captain Jacquart, an engineer in the Department of Roads and Bridges of the French army, and were found to agree with the facts empirically observed. Since they are too technical to quote here in detail, we confine ourselves to reproducing the following final paragraphs dealing with the practical consequences involved.]

There is a tendency to the formation of a meander when the rapidity of the current is diminished either because of a decrease in the degree of declivity or because of resistance offered down stream as by a sand bank or a contraction of the channel. This tendency is sometimes to be attributed to deposits of gravel but is most frequently due to a resultant of pressures and of the forces of inertia acting laterally in a manner closely analogous to the buckling of solid bars when compressed.

The incurvation when once begun is increased by the effect of the centrifugal force of the eddies produced within the curves and by the transport of the materials of the bed of the river to the point where the obstacle occurs. The engineer, therefore, who plans to build a bridge or any other construction offering resistance must take into consideration not only the raising of the level of high water but also the possible erosion of the banks of the stream above the said obstacle. Consequently the only practical guidance is to be found by a study of what has occurred in the remainder of the same water course.

The repetition of the phenomenon described above in a stream of water which presents an alternation in the degree of slope or a succession of sand or gravel banks will occasion a series of successive meanders exhibiting a longitudinal profile like that of a staircase as represented in Fig. 6.

The protection of the banks need not be continuous. It may consist of submerged piles properly spaced, which bear a certain analogy with the fixed points arranged in a bar of metal to prevent buckling.

The question is often asked whether it would be preferable when regularizing the course of streams to make the new bed follow a straight line or a curve. The foregoing remarks indicate that the straight line involves the minimum of stress as concerns the erosion of the banks, consequently there is no reason why it should not be used, as is very frequently done, in fact, in Switzerland (Upper Rhone, Aar, etc).

However, from the navigator's point of view the straight course is open to the objection of causing an increase in the declivity and consequently of the excavation of the bottom. Upon the French Rhone (where the piles, moreover, constitute a *regularization* of the existing bed rather than a *correction*), it is estimated that a channel having a well marked but not excessive sinuosity is easier to maintain in a stable state than one which is nearly rectilinear, since the latter may wander in times of low water in the smaller bed. This reminds us of the preference often given to a curve of large radius over a tangent in the planning of railway tracks.

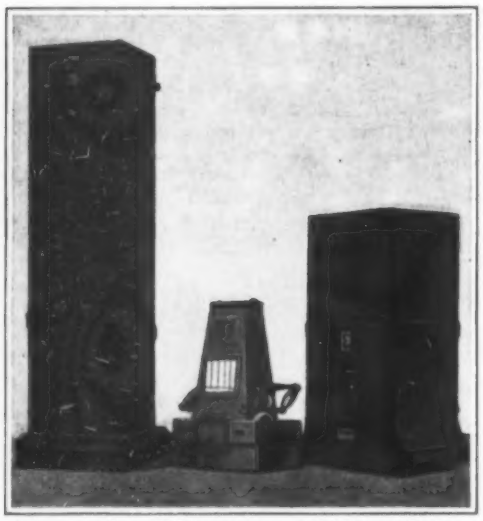
When the declivity increases in the down stream direction the tendency to buckling is replaced by a tendency to straighten. The main current abandons the concave or external side of the curve in spite of the action of centrifugal force and establishes itself near the convex or interior side. The same thing occurs at a great many points during periods of high water the relative importance of the obstacles being changed while the variations of superficial slope sometimes undergo a change of direction. The current then digs a trough opposite the convex border and this at times causes an island to be formed or transforms a meander into a dead arm.

Recent Progress in Aerial Photography*

Remarkable Improvements During War and Applications To Peace-Time Needs

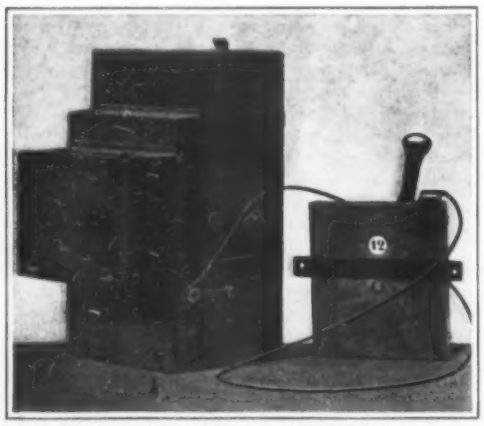
By L.-P. Clerc

Some fruitful photographic reconnaissances carried out in August, 1914, by a number of airplane observers in the Yser, the Marne and the Lorraine sectors drew attention to the value of this method; but it was not until the discovery of a German apparatus for aerial photography realized the need for installing a regular airplane photographic service at the front. In December, 1914, a section of aerial photography was created



Air camera in metal in center. At right and left are the "night table" and "grandfather clock" (18x24). French types of early 1915

in each of the French armies, but it was exceedingly rudimentary both as to personnel and material equipment. For example, at first each section had only two 13 × 18 cm. cameras at its disposal with a staff of one enlisted photographer, one junior officer draughtsman and one officer without specified duties. In spite of such small beginnings the results obtained were so important that the military authorities soon recognized the necessity of developing this branch of the service. By March, 1915, the staff of each S. P. A. (*Section photographic aéricune*) had been increased to 6 photographers, the first apparatus had been replaced by improved types, the remaining equipment had been improved and enlarged, and each section had also the entire use of two motor cars, one fitted as a travelling laboratory and developing room and the other being a small service truck. About this time also we began



Italian 13x18 of f = 0.24 m. All manipulations semi-automatic by means of the lever at the right

to pay attention to the special instruction of the staff.

Aerial photography was at first confined to the squadrons of the army and a very limited number of proofs were struck off, but the importance of the service rendered by this branch, particularly during the Artois offensives in March and June, 1915, soon led to the general use of photography throughout the army and caused the distribution of thousands of proofs among all ranks. The original 13 × 18 cm. cameras each of which was provided with only one magazine holder carrying one dozen plates was replaced by

*Translated from *La Science et La Vie* (Paris); photographs by courtesy of the same.

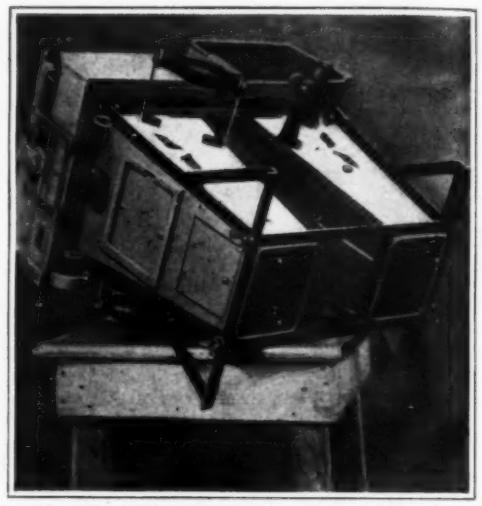
French type of 1917. f = 1.20 m. magazine of 12 plates; high level reconnaissance

metal apparatus containing three interchangeable magazine holders. To these were added 18 × 24 cameras of wood with separate frames not used in aerostier companies. . . . It was then decided to increase the number of sections in the department of aerial photography, and in September, 1915, a section

German 13x18 in 1916. Body is wood cloth-covered. Magazine is removed

of photography was added to each squadrille of an army corps besides those employed in connection with bombarding and reconnoitring. These newly installed sections were each provided with an improved laboratory motor car, with two 13 × 18 cameras having a focal length of 0.26 meters, and soon afterwards with an 18 × 24 camera having a focal length of 0.52 meters. The staff consisted of four photographers and a draughtsman, one of whom ranked as head of the section. These new sections first went into action in September, 1915, in Artois and the Champagne and the staff soon proved too small to meet the increasing demands for photographs; it was, therefore, increased by the addition of two photographers, a draughtsman and an officer observer ranking as Chief of Service.

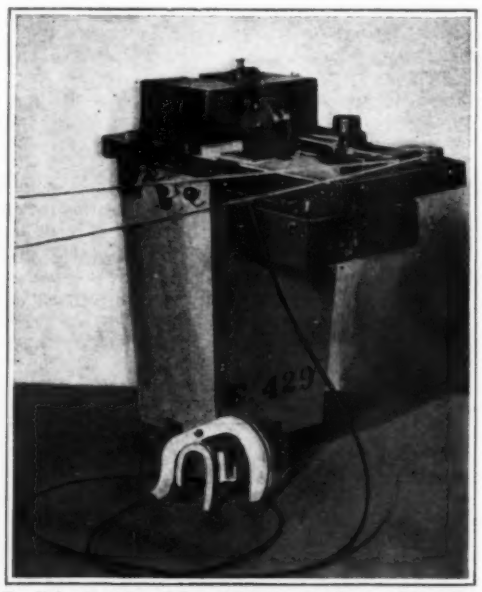
For the preparation of the Somme offensive, rendered useless by the German turn in March, 1917, and for the preparation of the Champagne offensive in April of the same year, many of the sections were required



French twin apparatus, 13x18, of f = 0.26. Stereoscopic views made by successive individual exposures at a few seconds' interval

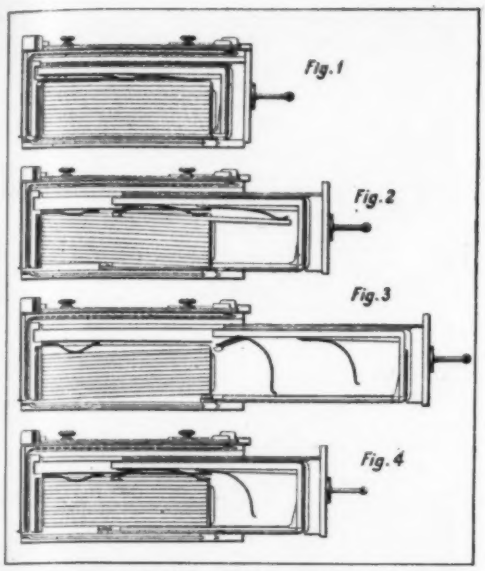
to turn out daily more than 4,000 prints struck off from some forty negatives.

To the apparatus already mentioned there were added cameras of the dimensions 18 × 24 with a focal length of 1.20 meters and the various 18 × 24 cameras which had been provided up to that time only with separate plate holders were furnished with interchangeable magazine holders holding a dozen plates each. Automatic apparatus of various models was also put in service and proved highly valuable in many circumstances because of the greater freedom their use permitted the staff. . . . In the hands of young observers however these models were wasteful when a photographic expedition was regarded merely as a chance to "beat the record" of the number of expos-



English 10x12½ of f = 0.25 m. Cords regulate plate changer. Flexible cable shutter release

ures made. This frequent immoderate waste was to some extent also encouraged by the habit of the commanding officer in setting down in his daily record of aerial operations not the surface of the ground covered photographically by each squadrilla but the number of exposures made. For this reason many observers used three dozen plates on a reconnoitring tour when eight or ten would have been ample; furthermore, they



Gaumont 12-plate 18x24 magazine (1917)

had 150 prints struck from each of their negatives, even those which were quite unnecessary.

Besides many improvements in equipment the S. A. P. were provided in April, 1917, with apparatus for printing in quantity as well as with automatic machines for developing and finishing the proofs, and finally, with a truck having a very comfortable photographic car in tow.

In December, 1917, the staff of the section was finally enlarged to include an officer or adjutant acting as chief of section, eleven photographers (an under officer and two corporals) two *magasiniers* in charge of supplies, four draughtsmen (one under officer and one corporal), four record keepers in charge of expeditions (one under officer and one corporal), a conductor and a mechanician-electrician. Furthermore, each aviation field of the army contained a warehouse holding photographic supplies and products and a workshop for repairs of various sorts.

The technique of the S. P. A. made steady improvement both in perfection and in rapidity of work. A first lot of proofs was generally ready two hours after the landing of the airplane, about five proofs being struck off from each negative; a second lot of about 20 or 30 proofs to each negative were sent out two or three hours later. . . . If we take into account the fact that before printing the negatives had to be identified, studied and provided with various data such as number, date, hour, scale, name of locality, orientation, etc., it will be seen that an immense amount of work was accomplished daily by the personnel of the sections, which were recruited exclusively (so far as privates were concerned) from territorial or auxiliary troops.

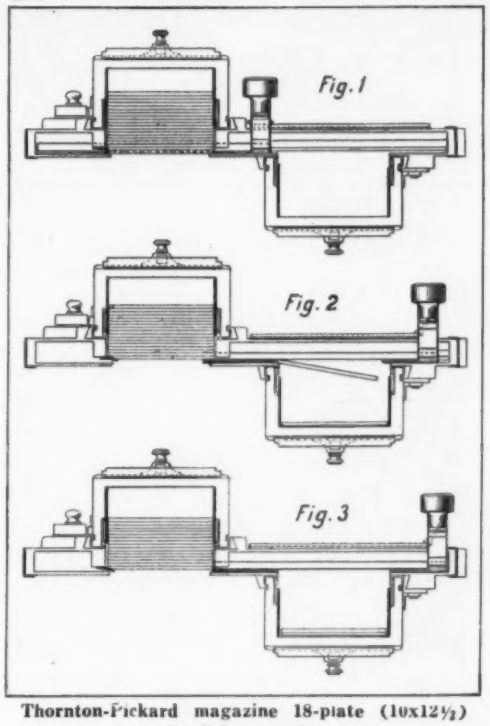
In cases of particularly urgency such for example as the verification of destruction before the launching of an attack, a dozen proofs were finished within half an hour after the landing of the plane and could be thrown down immediately in the form of a "loaded message" from a scouting plane to the officer requiring it.

The difficulty in obtaining fresh supplies of sensitive paper and the consequently increasing importance of aerial photographs led to the installment in 1918 in the various "groups of armies," of phototypic printing plants. Most of these plants were furnished with machines recovered from evacuated cities, the central plant being stationed at Versailles. This service not only turned out large quantities of photographs with great rapidity but attained an enviable degree of skill.

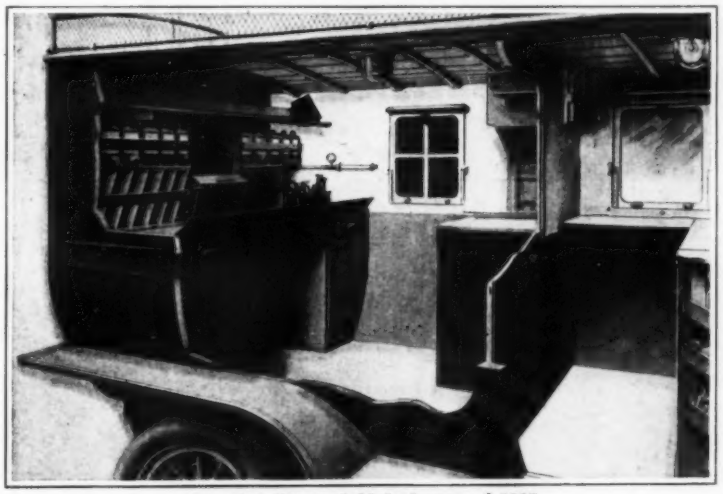
THE ENGISH SECTIONS.

The photographic service of the Royal Flying Corps (military aviation) was created in January, 1915, with a central laboratory for each army and a photographer for each squadrilla, the duty of the latter being the regulation and repair of the instruments and the loading and unloading of the plate holders. The exposed plates were carried by motor cycle to the central laboratory where developing, printing, etc., were attended to. The cameras employed in British military aviation were all of the dimensions 10 × 12½ with a lens having a focal length of 0.2 meters to 0.3 meters. At first flexible apparatus were used but these models were soon abandoned since they were not sufficiently rigid for service in the air; an attempt was also made, but without success, at tele-photography. Contact prints were rarely made since the English service was provided from the very beginning with enlarging apparatus and all the proofs, which were very few in number, were enlarged either to 16 × 21 cm. or to 40 × 50 cm.

The first results obtained were distinctly superior to those of the French army photographers, thanks to the rational employment of ortho-chromatic processes and the use of appropriate sensitive papers yielding sharp contrasts. In the course of 1915 a semi-automatic apparatus was invented, some examples of which were employed upon French military monoplane avions; the principle upon which these were constructed was applied later in a great many apparatus constructed for army use by various French observers. The photographic department was extensively developed in the English army and there were few scouting or fighting planes which went up without being provided with a camera. The study of rear lines of the enemy was particularly well developed and it was due to English photographs alone that in March, 1917, the existence of the famous Hindenburg line was revealed.



Thornton-Pickard magazine 18-plate (10x12½) English magazine



French military field-darkroom of 1915

In 1917 English military aviation was provided almost entirely with automatic apparatus. All manoeuvres except the release, which was left to the discretion of the pilot, being effected by a screw moved by the force of the wind (with respect to the avion); the only duty of the passenger consisted in replacing the empty plate holder by a loaded one.

The obtaining of a sufficient number of suitable photographic lenses roused as much anxiety in England as in France, but the English army solved the problem by a device which could hardly have been adopted in France for political reasons—they advertised, namely, in the technical press offering high prices for suitable lenses and making it obligatory to declare their possession.

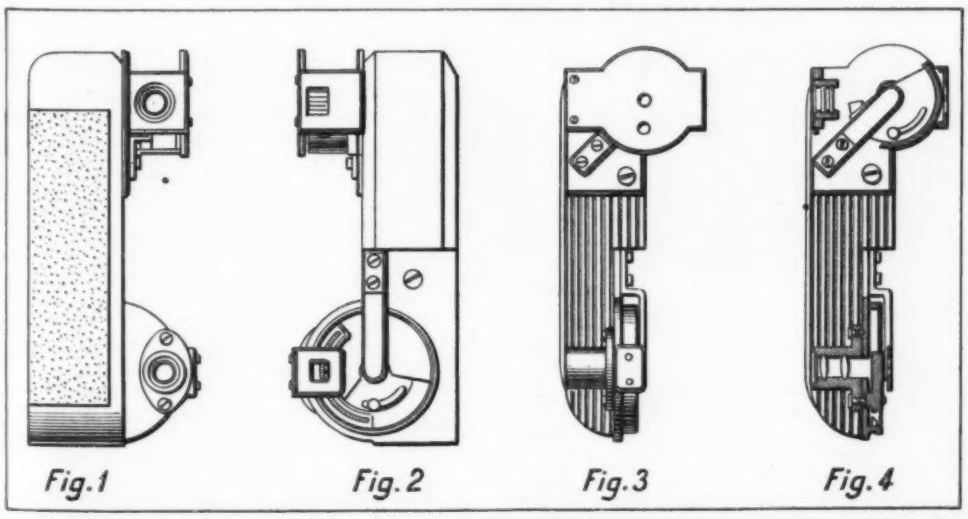
IN THE ITALIAN ARMY.

The Italian army possessed even in times of peace a well-organized photographic service for long distance surface photography, but did not develop its aerial photographic service to anything like the same extent. A 13 × 18 cm. camera with a focal length of 0.25 m. was employed; this machine was constructed on the principle of the old so-called "detective" apparatus, all the manipulation being accomplished by means of a lever connected with the apparatus by a flexible control; only a dozen plates per trip can be exposed in the original apparatus, but as adapted for French use it holds 3 dozen and has been of much service. Of all the various instruments employed during the war this alone is provided with a lens shutter instead of a plate shutter.

IN THE GERMAN ARMY.

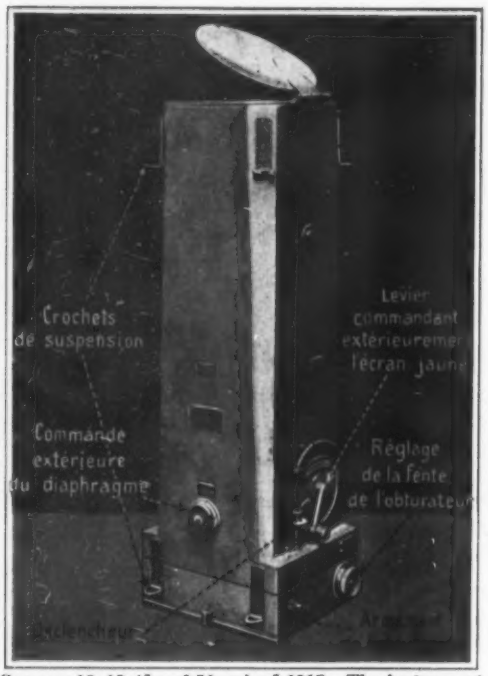
Even in times of peace the German army attached great importance to the topographical application of aerial photography. The "Vermessungs Abtheilungen" or Survey divisions were provided with apparatus for rectifying oblique photographs, and in order to facilitate this work quite a large number of aviation photographic apparatus were provided with automatic slant indications.

In spite of the traditional superiority of the German optical industry their lenses proved distinctly inferior to those of French or English make.[2] . . . At the be-



German devices for recording inclination of the plate—upper plumb moves an engraved glass cylinder whose axle is parallel to one side, the lower moves a graduated glass sector whose axle is parallel to the lens axis. Auxiliary lenses cause the graduations to record on the plate when the latter is exposed.

[2]The English developed superior lenses during and under stress of the war.—EDITOR.



German 13x18 (f = 0.50 m.) of 1917. The instrument is reversed in service

ginning of the war they had nothing but 9 × 12 cm. apparatus with a focal length of 0.25 m.; afterwards they employed 13 × 18 cm. with a focal length of 0.5 m., 0.7 m., or 1.2 m.; also an automatic film apparatus with a focal length of 0.22 m. and 5 × 25 in dimensions, with the shorter side parallel to the line of travel; and finally, in 1918, a 24 × 30 machine with a focal length of 0.50 m. All these except the two last named, were provided with interchangeable plate-holders each holding six plates, and a large number of these "magazines" were usually carried on each scouting trip.

In the French army care was commonly taken to insure the vertical position of the optical axis during the exposure of the plates and the apparatus was suspended within the fuselage so as to attain this end; but the German observers nearly always preferred to take oblique photographs and so nearly all their machines were arranged to be held in the hand, except, of course, those of very great focal length.

In January, 1917, field squadrilla No. 266 possessed two 9 × 12 cm. cameras with focal length of 0.25 m.; two 13 × 18 cameras with focal length of 0.5 m., and one 13 × 18 with focal length of 0.4 m. At the same period each army had at its disposal, while on duty, six squadrilla especially devoted to photography, three for first line scouting and three for long range scouting. Each squadrilla had a photography section (with a crew of 4 photographers, one of whom was an under officer) installed upon the terrain, with a towed laboratory car. Each squadron (group of squadrillas) possessed a more important photographic section including in its staff draftsmen and officers charged with the rational interpretation of the views obtained; this section was charged particularly with the task of making enlargements and utilizing stereoptically the photographs taken by the squadrillas. Only a few proofs were struck off from each negative, a number never exceeding 40 and this but rarely.

IN THE OTHER ARMIES.

The Belgian, Russian, Rumanian, Serbian, and American Armies had apparatus identical with those of the French Army; the Austrians used German machines, but their operators were usually very mediocre.

SPECIAL TECHNIQUE OF AERIAL PHOTOGRAPHY.

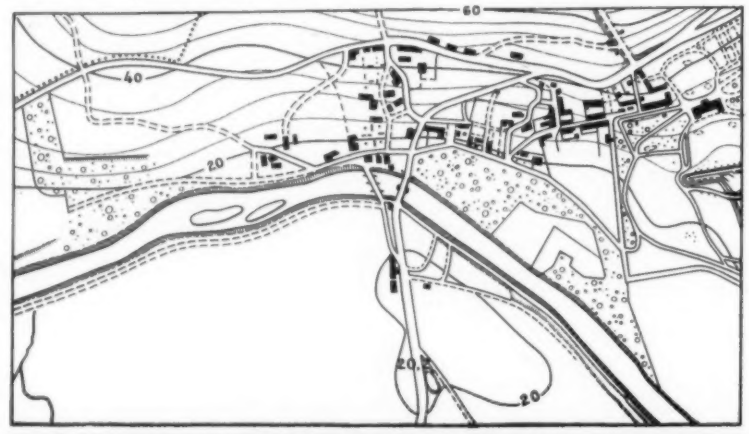
The special circumstances conditioning air photography at great heights—sometimes as much as 6,000 meters—involve a technique in the construction and use of the apparatus, as well as in other regards, which differs in many respects from that of earth photography.

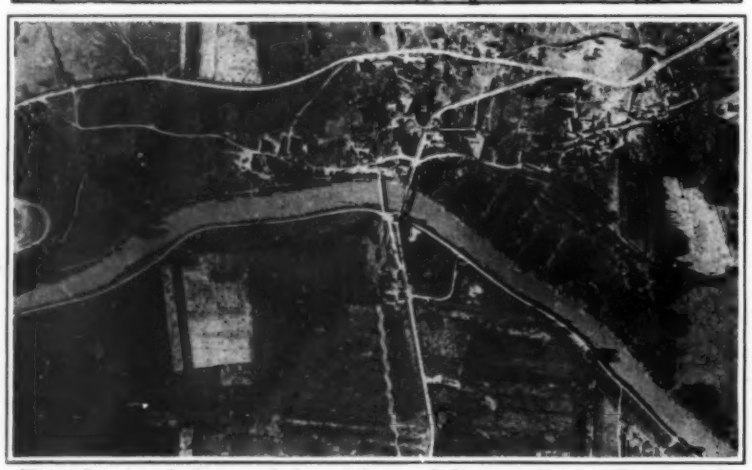
The great distance of the instrument from the object requires the employ of lenses of great focal length, to the exclusion of "tele-photo-lenses;" this involves the use of heavy and cumbrous apparatus, especially since the great expense of each flight makes it necessary to carry a large number of plate-holders so that the trip

Farman plane fitted with French panoramic device, 18x24, at bow

will be worth while. Such apparatus could hardly be held in the hand, since this would hamper the operator's freedom of motion; furthermore the attempt is made, except in special circumstances, to obtain a vertical sight in making the exposures, so that the photographs will differ as little as possible from a map, at any rate in a region which is comparatively level [pen accidentée]. Hence the apparatus is suspended, the vibration of the motor is counteracted by shock-absorbers as well as possible, and special care is taken to avoid pendular oscillation, which is peculiarly prejudicial to the distinctness of the image.

The high rate of speed of the avion compared to the ground (the effects of which are the worse the larger the scale of the photograph) i. e. when lenses of great focal length are used or when the flight is made at a low altitude, requires that the exposures shall be very brief; hence the shifting of the plate and the resetting of the shutter must be very rapidly done. With lenses having a very great focal length and a very large aperture it is necessary to employ a plate shutter, but since in this case the various parts of the image are not photographed simultaneously, the image is distorted, and while this distortion may not be very apparent to the eye it is far from negligible where topographical application is concerned.





Map (above) and photograph from 2000 m. of the same district (French 13x18 of f = 0.26 m). Note the photo does not show two islets of the map.

French 18x24 (f = 1.20 m.) on a Salmson biplane

The vibration of the motor tends to produce a spontaneous loosening of metal screws, and until special precautions were taken to avoid this many lenses and other parts of the apparatus were lost during flights. Curiously enough, however, many lenses have been recovered quite intact after a fall from a height of more than 2,000 m. (6,500 ft.)—merely having the mounting a bit bent, but with the glass in perfect condition.

The often very considerable speed of the wind with respect to the avion and the enormous pressure resulting therefrom tends to cause flexions and torsions of all insufficiently rigid elements unless protected by the fuselage or a suitable shield.

The dust and humidity of the atmosphere arrest and diffuse toward the avion a considerable proportion of the rays which are most active with respect to the photographic plate, and even when the sky is very clear this produces an effect similar to that of an autumn fog; and the deeper the layer of air between the instrument and the terrain photographed, the more intensified this effect becomes. This *atmospheric veil*, which is similar to that over images of remote objects in photographs of very open country, can be diminished, though not entirely avoided, by the use of orthochromatic plates and yellow screens.

The absence of sharp contrasts between the various luminosity of the surface of the ground which tend to fuse all into a uniform gray tone can be compensated only by printing upon specially prepared "strong contrast papers." The method of manufacturing these papers has been considerably improved during the war.

(To be continued)

X-Ray Examination of Electrodes for Steel Furnaces

THE carbon electrodes used in steel making furnaces vary in size and reach no less than 20 inches in diameter; if during a melt portions fall into the steel-bath the whole cast may become spoilt or wasted. Sections were cut about 1 inch in diameter and submitted to X-ray examination, and the preliminary results do not appear to have been very encouraging. Where a uniform structure was noticed in the radiograph the "service quality" of the electrode is reported as "fairly good," while another electrode that gave by X-ray examination a coarse structure very full of opaque grains gave in service an excellent result. Faults in manufacture such as cracks and flaws are, of course, revealed. Further work on the subject will probably yield valuable results.—*Chem. News* (London).

Yttrium Mixed Metal*

A Preliminary Study in the Production and the Properties of the Rare Earth Mixed Metals

By J. F. G. Hicks

OBJECT OF AND REASONS FOR THE INVESTIGATION.

On account of the meagerness of the work done,[1] because the metal has never been obtained in other than powder form, and because of the possibility of commercial application of the metal or its alloys, the preparation of coherent "Yttrium Mixed Metal"[2] (analogous to the well-known "Cerium Mixed Metal") was undertaken. It was further intended to make a detailed study of the properties of the metal and of its alloys with the common metals. Depending on the source of material, such a metallic product should vary in composition and "atomic weight."

II. PREPARATION OF MATERIALS.

Powdered gadolinite was decomposed by boiling conc. hydrochloric acid, and the mixed cerium and yttrium earths precipitated from the filtered solution by excess of oxalic acid. The "atomic weight" of these mixed earths (by oxide-oxalate ratio[3]) was 104.14. The cerium earths were almost completely removed as difficulty soluble double sulfates with sodium, $R_2(SO_4)_3 \cdot Na_2SO_4 \cdot 8H_2O$, yielding mixed yttium earths of "atomic weight" = 100.16. It should be noted that the term "atomic weight" here signifies an indication of relative purity of material for starting, or of product, on a basis of Y = 89; the numerical values are used in analytical calculations of metal content of product, the components of the mixture not being separable by ordinary analytical methods.

The soluble yttrium-earth sodium sulfates were converted to chlorides, and the crystallized chlorides mixed with an equal weight of ammonium chloride and partly dehydrated at 115°. Five of the 6 molecules of water of hydration were thus removed; the removal of the sixth causes hydrolysis.[4] Complete dehydration was effected in an atmosphere of dry hydrochloric acid gas at 350-400°. The product was a pinkish yellow powder, melting at 850-900° to a clear amber-colored liquid, which solidified to a gray mass.

C. Matignon[5] makes note of the difficulty of preparation of anhydrous yttrium chloride free from basic salt, but says nothing of the dehydration in hydrochloric acid gas. This modification of his method has been repeatedly used with success by workers in this laboratory on a small scale for atomic-weight determinations; although difficult, it can be worked successfully for large amounts. While the writer's results are in harmony with Matignon's as to the contamination of normal chloride by basic salt, they are in opposition to his finding that "Yttrium chloride is not appreciably volatile at temperatures slightly above its melting point;" in fact, serious loss resulted from this cause during some of the electrolyses. Hopkins and Balke[6] state, in connection with the purification of yttrium chloride, that its volatility "was a matter of some concern."

Rare earth material was recovered from wastes precisely as has been described for working up gadolinite, with the exception of the separation of the cerium earths from the yttrium earths.

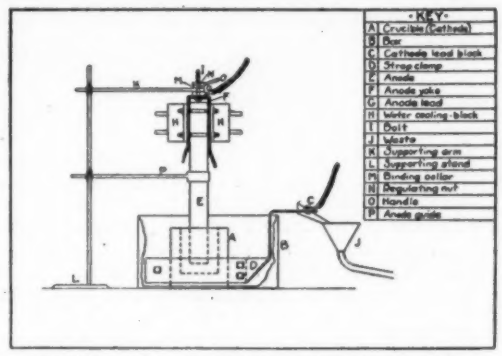
III. DESCRIPTION OF APPARATUS.

The final form of electrolytic cell is shown in the diagram. The cathode was made by cutting a 7-inch piece from a 6-inch cylindrical graphite electrode, and boring it to a depth of 6 inches, the inside diameter being 4 inches. In service it was lined with a thick paste of "alundum cement," which covered the inner walls completely, leaving the bottom of the cell available as cathode. This decreasing of carbon surface reduced very materially the formation of metallic carbides. The refractory lining was not attacked by the bath. Radiation was reduced by packing "Sil-o-cel" or sand tightly around the crucible. The anode was a graphite rod, two inches square and about two feet long, suspended and adjusted as shown. Such a device is very unlikely to fail in service, and has the additional advantage of capability of adapting new electrodes without waiting for the furnace to cool. In case of the necessity for auxiliary heating, a common Fletcher 5-inch "solid flame" burner placed beneath the cathode box answered well.

The apparatus for the final dehydration of the earth chlorides consisted of a tube of hard glass or quartz, in which the partly dehydrated chlorides were placed, connected at one end with a hydrochloric acid generator and at the other with a fume absorber. This latter was a glass tube provided with water inlets, and it efficiently prevented both hydrochloric acid gas and ammonium chloride vapors from escaping into the air.

IV. EXPERIMENTAL PART.

The decomposition of the anhydrous chlorides by metallic sodium was first attempted by slowly heating



Final form of cell used in electrolysis of yttrium mixed metal

a mixture of the two in small crucibles lined with a paste of "alundum cement" and magnesia. The results were [not] very satisfactory, owing to incomplete reaction; passing sodium vapors through fused anhydrous chlorides was even less so. The product of some of the best runs by the former method was a powder somewhat resembling zinc dust in appearance, which the lens showed to be made up of a dark gray powder mixed with white particles. The entire mass was readily soluble in acids, and the usual "atomic-weight" determinations were therefore valueless, referring to total earth metal rather than to that liberated by the reaction. These methods were abandoned.

When the decomposition was carried out *in vacuo*, the reaction mixture was placed in iron or nickel boats, and these into seamless steel tubes. After exhausting to 3—1 mm., the charged tubes were inserted in a muffle previously heated to 1,100°; the reaction took place quickly and quietly. This method was adopted as the best chemical means for decomposing the chlorides because: (1) oxidation was reduced to a minimum; (2) by-products efficiently removed; (3) ease and rapidity of manipulation. Admixed material was removed by shaking with anhydrous bromoform in a Harada separatory funnel, using anhydrous chloroform as a regulative diluent. This applies also to metal produced by electrolytic methods.

The resulting metal was a black powder, of "atomic weight" = 122.4 (original material = 104.3), and showed upon analysis:

	Per cent.
Metal (R = 122.4)	95.70
Iron	1.66
Undecomposed RCl_3	2.30
Oxygen (by difference)	0.34

The results indicate a simple and easy method for preparing such a "mixed metal" on a large scale and of relatively high purity.

In the electrolytic methods, the anhydrous chlorides (300-500 g.) were charged into the crucible cathode, and the temperature slowly raised to complete fusion, after which the electrolysis was carried out in the usual manner. During both fusion and electrolysis a stream of dry hydrochloric acid was allowed to enter the crucible; this prevented hydrolysis by atmospheric moisture. The basic chlorides produced by such hydrolysis dissolve but slightly in the fused normal chlorides, as is shown by the formation of solid particles at the surface of the fused mass. These soon afterward sink, and it takes but a small quantity to render a bath viscous and unfit for further electrolysis. The addition of small quantities of common salt causes these particles to dissolve, and the bath reliquefies, but no good results were ever obtained after the pasty stage had once been observed. The corresponding phenomenon for cerium chloride seems not to have this ill effect.[7]

"Metal fog" was very noticeable in all electrolyses. The addition of salt, fluorspar, or calcium chloride had no remedial effect.

The "anode effect" was of quite fequent occurrence during the earlier experiments; runs in which it occurred were always worthless. Sometimes the evolution of halogen would recommence after interruption, but it was always thereafter intermittent.

Formation of carbides was also frequently noticed, until the matter of lining the crucible (except at the bottom) was worked out. In the case of baths of pure fused chloride, the carbide could only have been that of an earth metal, yet in the case where sodium or calcium salts had been added it could have been carbides of these metals. Indeed, it was always more noticeable in baths known to contain sodium, except the cryolite bath. The formation of carbides could be detected by the pungent "hydrocarbon" odor,[8] which was very noticeable as the bath cooled down; it is thought this is due to hydrolysis of carbides by atmospheric moisture. The absence of the odor during a run or when the bath was very hot, and the presence of it when the bath had been cooling for some time, might prove that the carbides decompose at a temperature below the melting point of the bath, and that they are formed as it cools, although it could with equal propriety be concluded that they are formed at the higher temperature but not hydrolyzed until the temperature becomes low enough to permit of the action of atmospheric moisture.

A series of small scale experiments was made with the object of determining which carbon electrode caused the formation of carbides. It was found that with carbon anode and iron or nickel cathode no "carbide odor" was noticed; with a carbon anode and either metallic cathode carbide odor was frequently noticed. This shows that a carbon anode is at least partly responsible for the formation of carbides during the course of an electrolysis.

Electrolyses were carried out using a current density of 6 to 10 amperes per sq. cm. at 10 to 13 volts; the temperature varied from 900° to 1,100°, the best runs being made at about 1,000°. The yield of such runs was a black powder, exactly like that produced by the chemical method above described; the average "atomic weight" was 120, and analysis showed:

	Per cent.
Metal (R = 120)	94.05
Iron	1.19
RCl (undecomposed)	0.82
Oxygen (by difference)	3.94

It is thus obvious that electrolytic methods will produce a material of the sort under discussion of equal purity with chemical methods, and perhaps of lower content of undecomposed material. The disadvantage of a higher percentage of oxide (doubtless due to the high temperature and much slower cooling) is apparent; this oxide may prevent coalescence when attempts at fusion are made. Loss by volatilization of yttrium chloride at this temperature (the crucible is open) has also been referred to as a disadvantage. It was estimated that about 1,700 g. of chloride was lost by volatilization; the loss by recovery processes is very slight —less than one per cent. Some of the volatile material was condensed on a piece of glazed asbestos held over the crucible during a run; it was a yellow powder, reacting positively for rare earths, and faintly positive for iron. An "atomic-weight" determination yielded the value 52.7 for the earth present.

Another series of electrolyses was made using a solution of 50 g. of yttrium earth oxides (atomic weight

(*Continued on page* 144)

*Abstract of thesis submitted to Graduate School, Univ'y. Ill.; and reproduced from *Jour. Amer. Chem. Soc.*

[1] Other investigators mention isolation of yttrium (pure metal), but only as incidental to other studies. Their accounts are, in the main, conflicting. See Wohler, *Pogg. Ann.*, 1828, *13*, 577; Popp. Inaug. Diss. (Göttingen), *Pogg. Ann.*, 1864, *121*, 186; Humpidge & Burnay, *Jour. Chem. Soc.* (Lond.), 1879, *35*, 115; Winkler, *Ber.*, 1890, *23*, 787.

[2] The name "Yttro-mischmetall" was originally proposed, but at the instance of Dr. C. W. Balke, it was changed to the present one, for the sake of analogy. Dr. Balke further pointed out that the term "Cerium Mixed Metal" officially means the alloy of cerium with the other cerium earth metals, as distinguished from pure cerium, and that the older term "Mischmetall" had been used to mean both, thereby resulting in confusion.

[3] *Z. anorg. Chem.*, 1905, *47*, 464; *Jour. Amer. Chem. Soc.*, 1916, *38*, 2338.

[4] Oral communication by B. S. Hopkins.

[5] *Compt. rend.*, 1902, *134*, 308.

[6] *Jour. Amer. Chem. Soc.*, 1916, *38*, 2338.

[7] Hirsch, *Proc. Am. Electrochem. Soc.*, 1911, *20*, 57; Thompson, *Met. Chem. Eng.*, 1918, *17*, 213.

[8] A strong odor similar to that given off when commercial calcium carbide is hydrolyzed. It will hereafter be termed "carbide odor" for the sake of brevity.

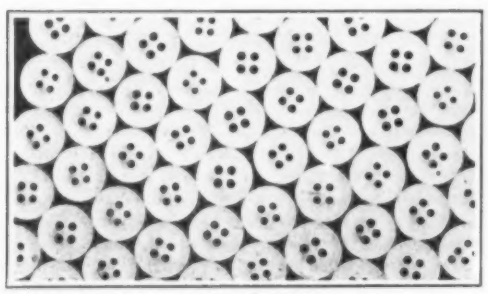
How Honeybees Produce Honeycomb—II*

From Nectar the Bees Make Both Honey and Wax, from Wax They Build Cylinders to Hold the Honey

By Edward F. Bigelow, ArcAdiA, Sound Beach, Conn.

[Concluded from Scientific American Supplement for August 16, 1919, No. 2276, P. 101]

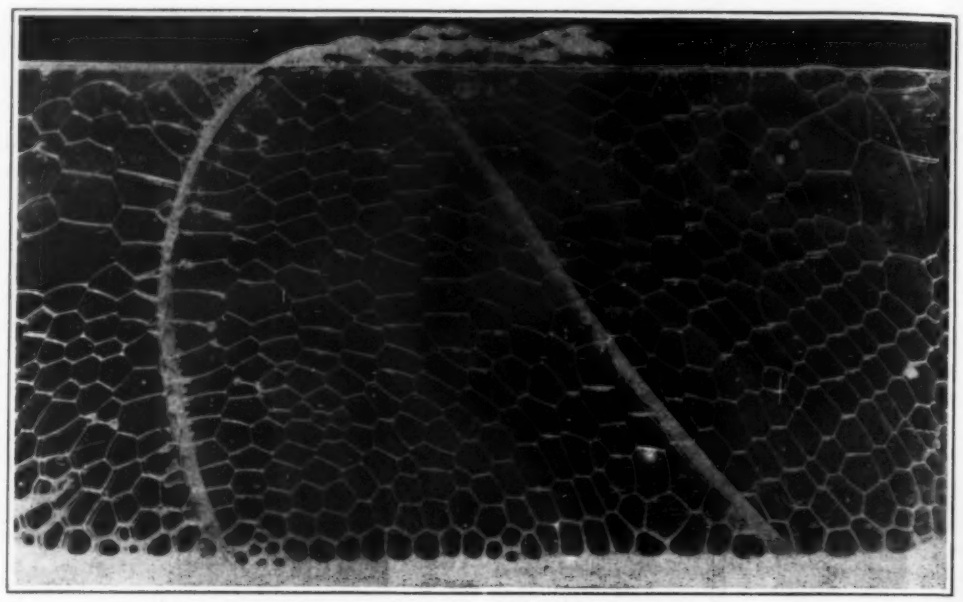
We would recall that old saying by Cheshire: "All nature apart from the mystery of life solves everything mathematically. The cricket ball flying from the bat of the tyro, the spray from the maiden's mop, the tiny soap-bubbles of the laundress's lather, as much conform to perfect mathematical solution as the path of a comet or the form of a star." A child may blow a soap bubble and toss it in the air. No credit can inure to the child for the beautiful spherical form of the mid-air bubble. That form is simply the result of a natural law. If the child blows several soap bubbles in contact with one another, they become beautifully hexagonal, but here again no credit is due the child. The hexagons are physically not biologically produced.



Each button has six others touching it. A hexagon is "a circle surrounded by 6 circles that have flattened its sides"

The edge of the honeycomb built wholly by bees is never hexagonal nor angular. The side is a curve and the cells immediately on that curve are spherical at their bottom and circular at their rim. All solitary bees work in circles. I have felt about this like Lowell when he argues in regard to the straight canals on Mars. He maintains that nature does nothing in straight lines. You never saw an absolutely straight tree, a straight mountain ridge, a straight brook in a meadow. You never have known a woodchuck to dig a square hole nor any other kind with angles, neither does the woodpecker make an angular hole. If we enter the realm of the honeybee and of other members of the Hymenoptera, we shall observe that no mud wasp makes angles on the sides of its cells. The carpenter bee does not bore an angular opening. All excavations and all nests of all forms of animal life are normally free from angular outlines. He that gives the matter consideration will naturally feel that the hexagons of the honeybee's comb are associated with something beyond and outside of biological law. This circular habit continues even with some of the social Hymenoptera. It is known to every boy that has dug out a bumblebee's nest, that the honey is in tubes of wax, or in separate and irregularly rounded cells of wax. Darwin was puzzled by this fact, because at one end of the series he had the cells of the hive bee in a double layer, each one hexagonal prism, and at the other the bumblebees that utilize their old cocoons which are circular, or make a wax tube. He reasoned regarding the intermediate form of the *Melipona domestica*, which was carefully described and figured by Pierre Huber, and decided:

"The Melipona itself is intermediate in structure between the hive and the bumblebee, but more nearly related to the latter; it forms a nearly regular waxen comb of cylindrical cells in which the young are hatched, and, in addition, some large cells of wax for holding honey. These latter cells are nearly spherical and of nearly equal sizes, and are aggregated into an irregular mass. But the important point to notice is that these cells are always made at that degree of nearness to each other that they would have intersected or broken into each other if the spheres had been completed; but this is never permitted, the bees building perfectly flat walls of wax between the spheres which thus tend to intersect."



Spherical soap bubbles, confined between glass plates become hexagonal cells

Therein is the secret. The honeybee has not *learned* to make hexagons, but she crowds so much into a little space, putting her tubes so close together that they intersect. The sides are flattened, and the cells become hexagonal. Only three forms can be put together without interstices—the square, the triangle, and the hexagon. The hexagon most nearly approaches the circle and would be well adapted to curved or circular larvæ. If the honeybee had plenty of room, she would make all her cells circular. This is proved by the circumstantial evidence, that when she has a sufficiently important larva to care for, she takes plenty of room and makes a circular cell for the queen. The cells at the edge of the comb, where there is no pressure on the sides, are in outline always circular, never hexagonal.

As pointed out years ago by Cowan, an English investigator, these "cells behave mutually like soap bubbles, which when isolated are round; but if they touch each other, the united films form a perfectly flat wall. If there are many, those in the center will be hexagonal, while those on the outside will have their free sides curved." This is exactly the situation though, as Cowan states, it is denied by some.

After the bees have manipulated the wax they press it down in a crowded irregular mass, which, under a microscope, looks about like a mass of mortar slumped off from the hod of the carrier. Then the bees scoop out the wax into little holes, and that scooping manifests itself as vestigial, circumstantial evidence in the pittings all over the queenbee cell which give it its peanut-shell roughness. Regarding this Cowan says:

"As the wax is scooped out it is put on the side walls, which are thereby thickened, and give the mouth of the cell a circular form, in all stages of its progress. Many cells are found into which a bee cannot enter, but as the wax is always added to the top edge she has only to work down inside a very little way, and we presume she does much in the same way that a bricklayer would do when building a chimney from the outside, into which he could not introduce his whole body."

Darwin made extended experiments regarding this, and found that the bees always scoop out the wax from spherical cavities.

"I separated two combs, and put between them a long, thick, rectangular strip of wax: the bees instantly began to excavate minute circular pits in it; and as they deepened these little pits, they made them wider and wider until they were converted into shallow basins, appearing to the eye perfectly true or parts of a sphere, and of about the diameter of a cell. It was most interesting to observe that, wherever several bees had begun to excavate these basins near together, they had begun their work at such a distance from each other, that by the time the basins had acquired the above-stated width (i. e. about the width of an ordinary cell), and were in depth about one-sixth of the diameter of the sphere of which they formed a part, the rims of the basins intersected or broke into each other. As soon as this occurred, the bees ceased to excavate, and began to build up flat walls of wax on the lines of intersection between the basins, so that each hexagonal prism was built upon the scalloped edge of a smooth basin, instead of on the straight edges of a three-sided pyramid as in the case of ordinary cells."

But the bee is a scraper as is the mason when he builds a chimney or makes a cement and stone wall. Have you ever noticed how he slaps on roughly a trowel full of mortar and spends most of his time in scraping the sides? So it is with the honeybee. She keeps piling up the end of a cylinder and then constantly goes into her cylinder and scrapes the sides to make them thin. It is this going in that does the hexagonal work and is the exact equivalent of what I did when I pressed a solid on the soap bubbles. She does more than scrape. Her body is covered with hair, even feathers one might almost call them when they are viewed under a microscope. She is like a gun swab and when she pushes into that cell she pushes out the sides. If there is only one cell as in the case of the queen bee cell the pushing out of the sides makes a cylinder, but there are other bees making other cells and they are close to this and it is this pressure on the sides, with not the slightest intent nor skill on the bee's part, but purely the effect of a mathematical law,

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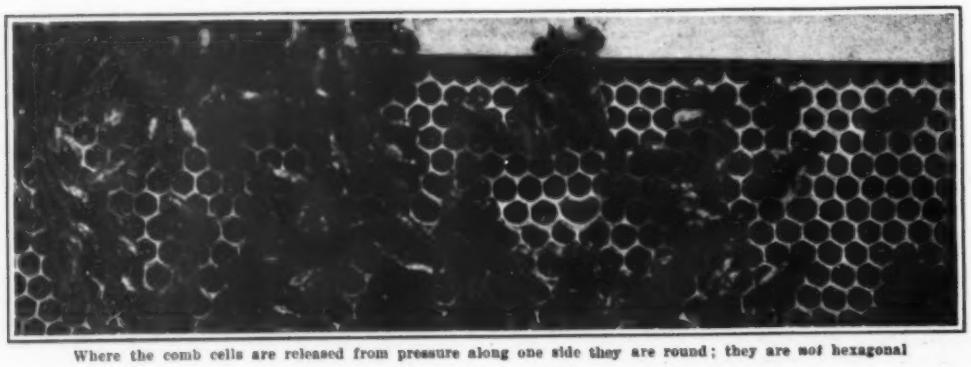
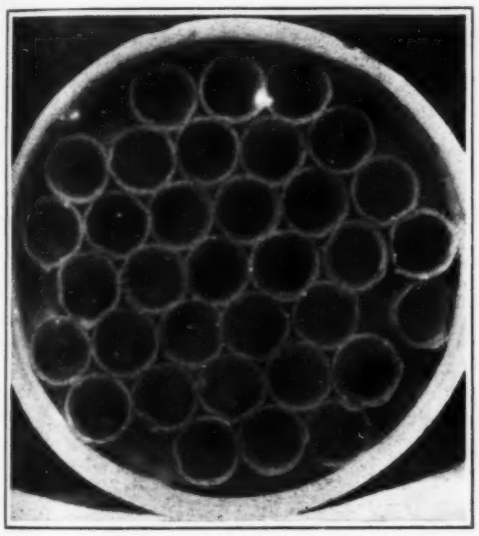


Where the comb cells are released from pressure along one side they are round; they are *not* hexagonal

that makes the hexagon. As Cheshire told us years ago, "The geometrical relations, which embellish the wax tracery of the bee are the necessary result of her mode of proceeding. And mathematics is no more her endowment than it is that of the soap and water we have been considering. These wonders come because the whole creation is founded and sustained by the great Geometer, whose laws of weight and measure neither falter nor vary, so that, for the advantage of man, the experience and observation of the past make him the prophet of the future." And Cheshire proceeds to make it perfectly plain that a single cell made by a honeybee is always circular. The queen cell is an example of this. "It is circular—the typical form—in cross section, because it is built alone, and is made to grow with the growth of the grub it contains."

If a number of wax cups, such as are supplied by the manufacturers for queen cell starters, are placed compactly together and then warmed until the wax is plastic, and into each one of these is thrust a small circular brush, so as to push out the interior, the cups will, by the pressure of the brush, become hexagonal in outline.

Note carefully that whenever comb is turned out on the artificial foundation that the bee commences at the very start to build circular piles of wax upon the hexagons. The cells of honeycomb are always circular in outline on the edges of the comb where there



Wax tubes heated to the temperature of the hive become hexagons when expanded by inserting brushes

are no others to press against them. We give the honeybee hexagons as a foundation, but when she makes comb she never makes hexagons. There are no hexagons *made* at the base of growing comb nor at the top of the cells. There never has been and there never will be, for the reason that the honeybee always *works* in roughly circular lines.

THEY ALWAYS WORK IN CIRCLES.

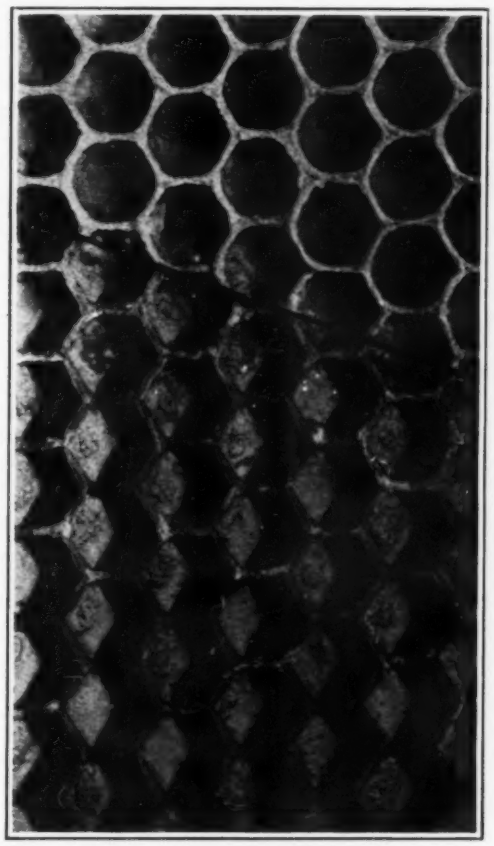
Just one more photograph, but a remarkable one, that I have recently secured, to show that in every stage of the upward growth of the cells the work of the honeybee is in circles, it has been strenuously maintained by some opposers, who ingeniously yet incorrectly argue, that the circular coping is only for the finish at the top of the cells, to be there used for strengthening purposes. But why the cells need to be any stronger at the top than at the bottom is a puzzle unexplained.

The accompanying illustration shows how the bees build up the cell from artificial comb. The lower edge, and the first angular line, with the first row of full-sized cells, shows the comb foundation exactly as it is when it comes from the manufacturer's machine. It will be observed that on the upper edges of this lower row of cells the bees have begun their work by changing the outline from angular to circular. The top row is of nearly full depth, and practically completed. The two intermediate series are at varying degrees of depth. If any one can ask for more definite proof than this, the problem is to discover what would be for him an absolutely convincing argument.

It should be said, in addition, that this is not an unusual occurrence, but an ordinary observation that may be made time and again in the change from the angles, as manufactured, to the circles in all stages, as made by the bees.

The optical illusion hexagons on the surface of any growing honeycomb disappear the moment they are examined with eyes wide open. Take a collection of circular dots, or look at the ends of a pile of lead pencils with the eyes partly closed and looking through the eyelashes, and immediately they all become hexagonal. It is the old argument about the markings of the diatom called *Pleurosigma angulatum*. Note the accompanying expanse of circular black dots. Does any one doubt for a moment that these are circular? Look at them through your eyelashes with the eyes half closed and see what beautiful hexagons you will have. The appearance is really all owing to *imperfect eyes*. It is an optical illusion. All growing honeycomb held at a distance or reduced by photography will show the thing dimly. Examine the comb with clear strong light and under a pocket lens of an inch focus, and every one of those hexagons will vanish and the comb will become a plane of circles.

I have entered extensively into this monographic exposition, because of the many attacks that have been made upon my claims by some of the most practical authorities in the United States. Articles on this subject, in which I have asserted these facts, have

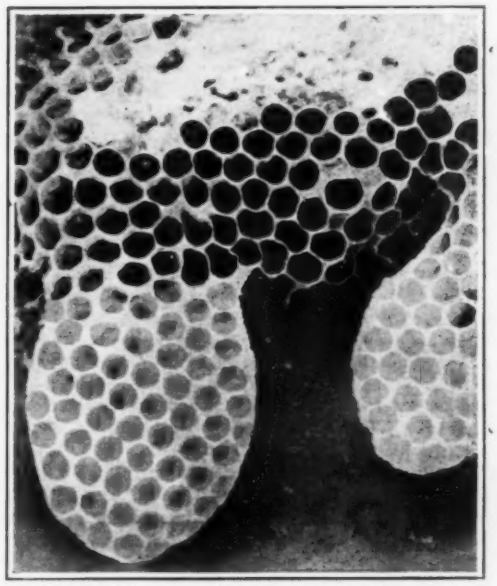


Below, artificial foundation geometrical hexagons; above, converted into *circles* by the bees

been refused by two important bee journals and I have been not a little ridiculed because I believe and say that the bee does not build hexagons. Some things are the outcome of definite physical laws and have nothing to do with intent nor with learning.

Perhaps this opposition is based on the fact that it exposes the error of making artificial comb foundation in hexagons. Theoretically this is wrong, yet I believe that the error makes no practical difference. The manufacturers of artificial comb may have reasoned in this way: "If we examine the middle division of a honeycomb, we find that it is formed of the sides of cubes. We will therefore mold our sheets of wax with cubical indentations." But this comb foundation is for the beginning, not the end nor the middle. The bee starts with parts of spheres and circles, and physical law only, not the bees, finishes with cubical indentations. The bees ask for circles, and you give them cubical depressions. It is a plain example of getting the cart theoretically before the horse. In the production of comb foundation, circles and spheres should come first in what we supply to the honeybee in starter sheets of wax. I assert, without hesitation, that all comb foundations that offer such cubical indentations are logically and theoretically wrong. I doubt whether any so-called practical beekeeper will support this statement, but I am confident that the manufacturers will oppose it. Opposition cannot change the facts in the case. ***I cheerfully admit that practically the foundation as supplied by the manufacturers may be even better than flat sheets of circular surface ridges.*** I am not discussing the practical point, but the theoretical, the purely scientific point. A thing theoretically right may be practically wrong. Any bee-keeper may witness an exemplification of this claim if he will place some of this artificial comb foundation within the hive and note that the honeybees will invariably, in their very first work, change hexagons and cubical indentations into simple circular rings. I have examined hundreds of specimens of natural honeycomb made wholly by the bees, and as many others of the beginning of artificial comb foundation, from the moment when the first masticated particle of wax was placed on the ridge, but without a single exception I have found that the bees worked circularly or spherically. In such cases like comb built between the top of the frame where there is room for only one or two rows of cells, or on the edge of the honeycomb next to the attachment to the wood, the cells invariably are circular in outline.

The foregoing illustrations and discussion called forth a large number of commendatory and confirmatory comments from the ablest students in this and correlated fields and should forever establish the fact that the hexagons in the combs of honeybees are the outcome of strictly physical laws and not the result of blind instinct nor of any biological "intent" and still less of anything in any way approaching an intelligence almost superior to human intelligence.



Queen cells and points of attachment free from pressure, are *circles*

MY THESIS AND THE DARWIN THEORY.

In my article on "How Honeybees Produce Honeycomb," I made this statement in regard to the bees:

"They never yet have been able to make a hexagon nor to learn how to make one, Darwin and a host of minor lights chiefly the utilitarian beekeepers, to the contrary notwithstanding."

I did not mean to imply that I disagree wholly with Darwin and with the utilitarian beekeepers for on some phases of the discussion I am in perfect agreement with them. In developing the demonstration I could not explain all points of view, but several scientific friends who cordially support my thesis say that Darwin held a similar opinion and that I am in accord with him. One learned professor says that I do injustice to Darwin when I imply that there is any disagreement.

Darwin was a careful observer, and was nearly always correct in his observations and in the statement of facts, but not all of us will agree with all his deductions. He was so intent upon strengthening his thesis of the struggle for existence, natural selection, survival of the fittest, etc., that he used some facts as a part of his philosophy that in my opinion do not belong there. The very fact that in "The Origin of Species" he devoted space to the subject of comb building shows that he regarded it as part of his theory of evolution. Many aspects of honeybees and perhaps even of comb building, rightly belong in a philosophy of evolution but the structure of the hexagons does not. I quote from him:

"By such modifications of instincts which in themselves are not very wonderful,—hardly more wonderful than those which guide a bird to make its nest,—I believe that the hive-bee has acquired, through natural selection, her inimitable architectural powers." . . .

"That individual swarm which thus made the best

(*Continued on page* 143)

The Semi-Diesel Engine*

The Structural and Operating Characteristics of the Hot-Bulb Engine and Its Economic Position

By H. F. Shepherd

COMPLETE theory of the semi-Diesel engine is still largely unwritten. At present the constructions are legion, varying not so much in mechanical details that may not be important, but rather in approach to the ideal of working involved in the stereotyped catalog or textbook description. Out of this variation arises much sales talk, and truly the purchaser without previous experience is confounded by superlatives. In what follows an attempt will be made to deal sanely with the most important variations in design and characteristics of operation from the viewpoint of the designer, also with the commercial relation between the true Diesel and the semi-Diesel.

The latter term is rather loosely descriptive of a type of engine in which vaporization of fuel (at least in some degree) and ignition are provided for by spraying the fuel charge toward a hot surface large enough to intercept all the fuel that traverses the combustion space and hot enough to produce ignition of the fuel in conjunction with the compression. The compression is lower than that employed in Diesel engines, varying actually from 150 lb. to 250 lb. per sq. in. for two-stroke-cycle types and from 180 to 300 lb. per sq. in. for four-stroke-cycle types. The injection of the fuel charge, either with or without compressed air to assist the atomization, takes place just long enough before the firing center to allow vaporization prior to ignition at that point. Solid injection of fuel or mechanical spraying is almost universal.

ECONOMIC MERIT OF THE TYPE.

The ever-increasing manufacture of this type is possibly sufficient evidence of its economic merit; however, the purchaser may wish to make his own analysis. This hinges on low first cost and low attendance cost. Assuming that like percentages of the initial cost may be applied to both the true Diesel and the semi-Diesel types for depreciation, upkeep, interest, insurance, etc., and dividing these fixed charges by the yearly output in horsepower-hours, the difference may be balanced against the excess fuel cost incident to operating the semi-Diesel. It is scarcely wise to generalize on this point, as it is a local condition usually.

From the operating viewpoint, the semi-Diesel is simpler by reason of the omission of the high-pressure compressor and the gear necessary to operate the injectors and by the extreme simplicity of its injector or spray nozzle. In the plant of moderate size, where the yearly wage required to retain a man of skill and judgment may exceed the yearly fuel bill, a degree of simplicity of construction to meet the ability of the untrained operator is essential.

The semi-Diesel engine with mechanical fuel spraying exhibits one peculiarity that is not common to internal-combustion engines generally; that is, its operation is seriously influenced by its hot-surface temperature and in a lesser degree by its air-charge temperature at the time of injecting the fuel. This calls for compromise in its design and certain measures for compensation in order that it may operate satisfactorily at all loads.

A cold-air charge or a cold vaporizer at light loads will result in poor vaporization and possibly irregular ignition and the discharge of liquid fuel at the exhaust. The reader may be able to grasp this the better with the knowledge that it is a good fuel oil indeed that will yield 60 to 70 per cent of distillate when heated to 360 deg. C. The Southwestern crudes, and especially their residuums which are sold as fuel oil, and the California fuel oils seldom yield more than 40 to 50 per cent at that temperature. This alone would not be a difficult condition to meet, but at the other extreme the entering fuel must not meet too high a temperature.

The heavier petroleum fuels are subject to what is technically called "cracking" when exposed to high temperatures. This is essentially a rearrangement or alteration of the combinations of hydrogen and carbon which compose the fuel. The general result is the production of lighter oils (or their vapors), gas and free carbon. Controlled, this action is the basis of the Rittman process and the older Burton process for the production of larger quantities of light fuel than can be extracted from heavier petroleums by simple distillation.

PROPER CONTROL OF TEMPERATURE.

Repeating, the entering fuel must be subjected to a temperature no higher than necessary to vaporize it just before ignition. Some cracking will take place but it must be limited by proper control of temperature so that the least possible amount of uncombined carbon will be set free in mass form. This is not true of the Diesel engine with its air-blast injection. The reason is very simple. Oil introduced on a high-pressure air blast is so finely subdivided and distributed that each oil molecule may readily meet its oxygen and be instantly consumed. Oil introduced by a mechanical spray is delivered in microscopic drops even when sprayed at one or two thousand pounds per square inch. So-called high-pressure mechanical sprays work at from 5,000 to 7,000 and even 10,000 lb. per sq. in. They are not in extensive commercial use here, being too difficult to maintain, although such systems obviate serious need of careful temperature control by reason of their more perfect atomization.

If combustion begins at once on the surface of the globules of the normal moderate-pressure spray, their inner content will be "cracked," setting carbon free relatively in mass, which in this form will not burn completely in the time allowed by a single combustion period. Further, even if this does not account for all the inefficient combustion under excessive temperatures, even though each "drop" flashes into a little body of vapor if combustion begins before proper intermixing or diffusion of each small "cloud" through the air provided for its combustion, the burning on the surface will isolate the body of fuel vapor from its air with resulting escape of unburned or partly burned fuel.

The same reasoning applies to that part of the fuel that actually reaches the vaporizing surface. Vaporization and diffusion must, as far as possible, precede ignition and this necessitates temperature control between what are fortunately wide limits, but none the less limits. A red-hot vaporizer is fatal to combustion, the upper limit in modern designs being about 450 to 475 deg. C., or just below a red heat in the dark. Of course the term diffusion is not used in the scientific sense. Owing to the well-known "stormy" state of the air charge enduring after its introduction at high velocity, this action is very rapid.

THE SEMI-DIESEL AN EXPLOSION ENGINE.

The semi-Diesel engine is essentially an explosion or Otto-cycle engine. Thorough preparation for instant ignition and rapid propagation is essential to the nearest possible or practical approach to this ideal. Technically this is a more perverse problem than anything involved in the practical cycle of a Diesel engine. Practically, it is a successful alternative because its functioning devolves upon stationary or at least low-pressure elements of design that may be put into the hands of almost any class of labor.

Light-load operation with an engine of moderate compression and moderate spray pressure is made possible by deliberate retention of some of the exhaust gases; that is, the scavenging is purposely made more or less inefficient. This is accomplished in the case of the four-stroke-cycle types by the valve setting. Both exhaust and inlet are held open simultaneously for as much as 50 deg. on the suction stroke, permitting enough hot gas to be reaspirated to warm the air charge. The same result is accomplished with two-stroke-cycle designs by manipulating port dimensions and scavenging pressures and volumes. These measures, of course, reduce the available maximum mean-effective pressure, but there is little choice in the matter. The alternative is to use a high compression and a very high spray pressure, in which event the homely virtues of the semi-Diesel type are sacrificed to an ideal more satisfactorily realized in the Diesel type itself.

THROTTLES ON THE AIR INLET.

A compromise is sometimes effected by fitting a throttle on the air inlet for use at light loads, thus permitting more complete scavenging for full-load operation and therefore greater capacity. It would seem that this might serve as the sole means of compensation; however, experience has shown that regulation of the air-charge temperature alone is not sufficient. There must be some direct or independent means of cooling the hot surface under heavy loads as well.

The oldest method of regulating these temperatures is the injection of water into the power cylinder with the introduction of the air charge, the quantity of water fed increasing with the load either automatically by means of a governor-controlled pump or valve or by simple manual adjustment. The former is, of course, necessary for rapidly fluctuating loads. More recently, the hot ball or vaporizer has been fitted with an annular jacket through which a sufficient quantity of water is fed to maintain it at the proper temperature. This arrangement is not automatic as built to date.

Another device is a hot ball or vaporizer in the form of a drawn-steel pot let down into the combustion chamber. The fuel is sprayed against its bottom. A jacketed cover secures the pot in place and closes the interior from the atmosphere. This pot carries a charge of mercury boiling at 360 deg. C. An excess of heat is automatically dissipated by the boiling of the mercury at a consistent rate and the condensation of the vapor against the jacketed cover above, the cool liquid falling back into the boiling liquid below.

The design of the combustion chamber has but one theoretical requirement. As much of the air as possible should be massed between the fuel injection and the vaporizer at firing time. Air isolated in clearances and pockets cannot lend its oxygen to the burning of the fuel.

In this country and abroad two-stroke-cycle semi-Diesel designs predominate. The higher cylical temperature of the two-stroke-cycle engine for a given compression lends itself nicely to the requirements of the type, especially to light-load operation.

DESIGNS WITH CROSSHEADS AND WITHOUT EQUALLY DIVIDED.

The trade is about equally divided between designs with crossheads and those without. In the case of the two-stroke-cycle engine, the situation is essentially this: Air for scavenging is usually pumped by the displacement of the crank end of the piston. If a crosshead is employed, the crank end of the cylinder may be closed off by a bulkhead in the bed and a stuffing-box. If it is not used, the space within the crank box is utilized as the scavenging-air chamber and the main bearings must be packed air-tight.

The method of accomplishing this should always be investigated. The original way was to use simple non-adjustable bushings for the main bearings, depending on their fit and lubrication for air-tightness. After slight wear, aside from the play, when air leakage develops, the oil is blown out and the lubrication is seriously hindered. Somewhat later designs use soft packing in a stuffing-box at the outside of the main journals, and possibly the best is one adapted from European practice in which snug collars are fitted to the crankshaft close up to the throws and pressed outward by springs so as to seat against shoulders in the bearing housing or bedplate. These collars are splined to the shaft or slide on pins extending from a shoulder next the web and revolve with the shaft. Seat wear is, of course, taken up laterally by the springs. This gives the designer practically a free hand in the structure of the main bearings in the case of the single-cylinder engine. Multicylinder engines with crank-case compression present a more difficult problem in the design of the center bearings. When a crosshead is employed, main-bearing design involves no other problem than a convenient and secure adjustment and the application of any chosen means of lubrication. Among these latter, splash lubrication is made possible. This may not be the most modern and elegant means of lubrication, but it is at least intensely practical under adverse conditions. Its use is not possible with crank-case compression, as the oil would pass away through the scavenging ports.

No form of fuel spray or injector may be described as the best, as what is right with one form of governing system, fuel pump or combustion chamber or even development may be entirely unsuited to another. The most essential feature is that it shall cease delivery, or cut off, without dribble or spurt immediately on completion of the pump movement. This may be shown by operating the engine pump quickly by hand. A poorly designed injection system or one in bad repair may deliver almost a continuous stream of fuel instead of an intermittent, well-timed spray, despite what may be reasonably expected from the known mechanical movement of the pump.

All oil engines should be fitted with relief valves, preferably of the spring-loaded type. A cold start, leaving unconsumed oil in the combustion chamber or derangement of the spray nozzle may produce powerful premature explosions that have been known to wring the hubs from the flywheel spokes or to sunder the engine structure in some uncanny fashion when such valves are not provided.

*From *Power* (New York).

Desulphurizing in the Pig-Iron Mixer

A most interesting paper has recently come to hand on the theory of desulphurizing in the pig-iron mixer, originally published in "Stahl und Eisen" the latter part of 1916, and written by L. Blum, chief chemist at Esch, Germany. While this paper is most valuable in itself as regards the results presented and the theories drawn from them, it is still more valuable in its possible application to basic open-hearth practice. The removal of sulphur in the basic open-hearth is extremely difficult, and yet there are many times when it is necessary to attempt it. Particularly in recent years it has become increasingly difficult to make low-sulphur steels due to the increase in sulphur in the materials used in steelmaking.

It is possible that the application of similar methods to those used by Mr. Blum will be of great value in solving this most important problem. The paper starts by pointing out that the mixer has almost completely lost its importance as a desulphurizing agent, which was its chief purpose when first introduced in Germany. This is summed up in a statement by Osann in 1915: "We know that often there is no desulpherization in the mixer, without being able to determine the cause. The pig-iron lies dead in it." This observation is often confirmed in practice. The results with an ordinary 800-ton mixer of the general type used in that country since the mixer was put in operation are shown below:

Period	Sulphur in pig iron	Sulphur in mixer iron	Total sulphur removed
1913 to 1914	0.085%	0.057%	32.94%
1914 to 1915	0.069	0.050	27.54
First 6 months, 1915 to 1916	0.067	0.057	14.92

This decrease in sulphur removal in the ladles and mixer is striking, and the search for a satisfactory explanation was the reason for the work done. Brief reference is then made to the present theories of desulphurization such as the formation of manganese sulphide in the liquid metal, which rises to the surface because of its low specific gravity and is absorbed by the slag. Simmersbach estimates its specific gravity as 4.0 compared to 7.0 for the liquid pig iron. An Austrian theory is that alloys of iron, manganese and sulphur are formed which are lighter than the purer metal and rise to the surface like cream from milk. Here a slag is formed rich in sulphur which can be removed.

During the tapping of pig iron, its transportation in ladles and pouring into the mixer, there is considerable contact with air whereby manganese and silicon are oxidized and silicates of iron and manganese formed. Real mixer slag can therefore be considered as a mixture of these two silicates with sulphide of manganese. As further constituents there are found the slagged brickwork and lining of the ladles and mixer, and often large amounts of blast-furnace slag. The latter is proved by the presence of lime, which can only come from this source. The line of attack was to see the relation between the silica-manganese ratio in the mixer slag and the sulphur, for it had long been noticed that with a high manganese content the sulphur in the slag was high, and with high silica it was low. Accordingly a table was prepared of 70 mixer slag analyses showing silica, iron, manganese,

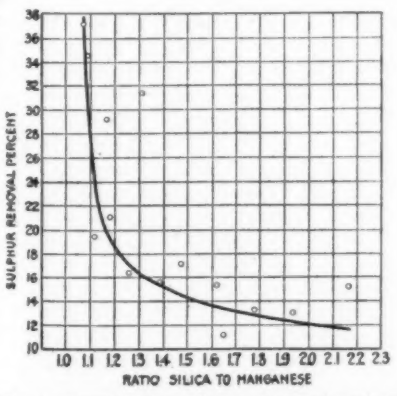


Fig. 1—Results of analyses of 70 mixerslags

lime, magnesia and sulphur percentages. By means of the lime content and the knowledge of the average blast-furnace slag analysis the sulphur and silica introduced by this slag were calculated, showing the sulphur and silica really in the mixer slag itself. The last column of the table shows the ratio of silica to manganese in the mixer slag.

The results given in this long table are shown graphically in Fig. 1, the co-ordinates being sulphur in the mixer slag and silica to manganese ratio. It is clearly seen that there is a definite relation between the sulphur contents and this ratio. With high basicity of the slag, that is, high manganese and low silica, there is high sulphur. With increasing silica content the sulphur quickly drops until with a ratio of about 2.00 the slag is practically free from sulphur.

The next thing to determine was whether there was a connection between the decrease in sulphur content of the mixer slag and the desulphurization of the iron in the mixer. Further tables were prepared, the first showing monthly average analyses for 13 months of the mixer slags and raw pig iron and mixer iron. The pig iron varied in manganese from 1.13 to 1.44 percent. The slag analyses were calculated as in the previous case and the clear connection between the silica-manganese ratio and the percentage of desulphurization is shown in Fig. 2. From the tables and diagrams the following conclusions can be drawn:

With an increasing silica to manganese ratio in the mixer slag there is a corresponding decrease in the sulphur contents.

There is also a corresponding decrease in the percentage of desulphurization of the iron while in the mixer.

The author then gives his explanation of these facts. If the mixer slag is considered as essentially a manganese silicate with the formula $MnO.SiO_2$, then there must be sufficient oxide of manganese present to combine with all the silica. If there is not enough then the excess of silica unites with the oxide of iron always present to form iron silicate. In the course of desul-

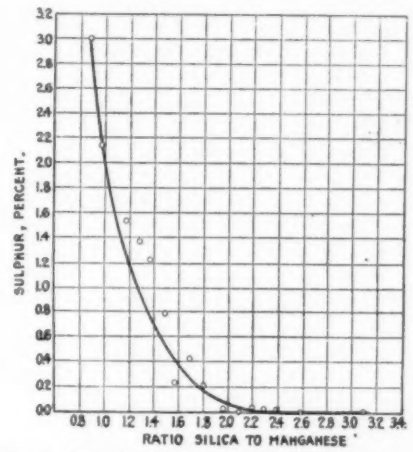


Fig. 2—Relation between Si-Mn. ratio and the desulphurization degree

phurization sulphide of manganese rises from the metal and enters the slag, but silicate of iron and sulphide of manganese cannot exist together. The reaction which takes place can be shown:

$$MnS + FeSiO_3 = MnSiO_3 + FeS.$$

The sulphide of iron is again absorbed by the bath, so that we do not have to deal with stoppage of desulphurization so much as back-sulphurization.

Next an attempt was made to determine how high the ratio, silica to manganese, must be to bring about the most thorough desulphurization possible. Slag No. 1 was taken from the first table, which showed 4.79 per cent sulphur. This slag shows 32.98 per cent manganese necessary to combine with the silica and sulphur present (not including that introduced by the blast-furnace slag), and gives a ratio of 0.82. Allowing a small excess it can be assumed that 0.80 is the proper ratio of silica to manganese in the mixer slag to bring about most complete sulphur removal. If this ratio is exceeded then the conditions are provided for the formation of silicate of iron with the attendant decomposition of sulphide of manganese, and decrease in the resultant desulphurization, until when the ratio rises to about 2.00 there is complete loss of desulphurizing power. The ratio of manganese to silica in manganese silicate is 1.09, the difference between 0.80 and 1.09 shows the manganese necessary for the formation of sulphide of manganese. The above theory explains the fact noticed sometimes that while in the mixer the iron takes up a slight amount of sulphur instead of losing any.

There are other conditions that exert an influence on the mixer slag, which do not depend on the analysis of the pig iron. They depend on the strong affinity that oxide of manganese has for silica. Due to this all substances rich in silica are attacked by the mixer slag, such as the lining of the ladle and mixer. Only the best bricks should be used, and those high in alumina. It is known that newly lined mixers give better results for desulphurizing, due to the brickwork being less attacked. The best results would be obtained by lining ladles and mixer with basic instead of acid material, such as is used for the basic Bessemer converter.—G. B. W., in *The Iron Age* (New York).

How Honeybees Produce Honeycomb

(*Continued from page* 141)

cells with least labor and least waste of honey in the secretion of wax, having succeeded best, and having transmitted their newly-acquired economical instincts to new swarms, which in their turn will have had the best chance of succeeding in the struggle for existence."

Aye, there's the rub. "Has acquired . . . her inimitable architectural powers," and "newly-acquired economical instincts." On the structure of the hexagons I agree as perfectly with Darwin as I would in a discussion of hexagonal soap bubbles, but I deny that there have been any acquired instincts, etc. Whenever hexagons were produced as a result of the honeybees working in wax, they were solely the result of physical laws as perfectly as they are now and for the same reason.

Let me illustrate by a partly imaginary story. I was taking a company of pupils on an inspection tour through an insane asylum and its grounds. As we were walking in a picturesque place, an attendant called my attention to an old man sitting in the shade of a tree with a basket of balls that he was tossing one after another in the air. Said the attendant, "I think you will find his answer interesting if you ask him what he is doing."

"Yes, sir," the old man said, "I am quite an expert in making these balls come down to the ground. When I was a young boy I began to throw balls into the air; they did not come down very well, but I have practised at this all my life, and now," as he tossed another, "you see I have acquired an instinct. I possess inimitable gravitation powers so that after these long decades of practise I can bring them down in a perfect manner."

In the building was another aged person with a clay pipe and soapy water engaged in blowing a pile of bubbles on a plate. Said the attendant, "That man thinks he is a geometric artist."

"Yes, sir," he replied, "I am a skilled man because I have all my life practised blowing bubbles. I began when I was a boy and obtained inferior hexagonal results within the pile, but there is nothing like keeping at it. I have practised all my life and," to illustrate his argument he dipped his pipe in the suds, "now, you see, I have acquired new soap bubble instincts that give me, sir, the title of geometrical, hexagonal artist. You will be surprised to learn that my first soap bubbles were like the cells of a bumblebee, but I have gradually worked through the various stages. It took me decades and decades but I have at last come to artistic perfection."

There is no doubt but that gravitation, not skill, brought the balls to the ground, and that pressure made beautiful angles within the pile of bubbles.

That is the way in which I feel about Darwin's claim as a part of his evolutionary theory that honeybees have learned how to make hexagons. The honeybee, instead of learning could not from the very first have avoided making hexagons, when she rubs off rough wax and scrapes the interior of her rising cylindrical pile of a series of circles of wax.

Development of the Iron Industry in India

The Indian Iron and Steel Company has asked for tenders for much of the material for a blast-furnace plant to be erected near Calcutta. The material will be shipped to India to be worked up there. The power-plant for the furnaces and a by-product coke plant are to be purchased in England. It is hoped to have all the materials shipped out within six or seven months. It is intended, so it is reported, to make this the nucleus of the largest iron and steel plant in India. The company has in view the building of two more furnaces and a steel plant. The installation will be located at Asansol, in the province of Bengal, in the heart of a large coal-field. The ore will have to be brought a distance of 120 miles. Of these deposits the company owns six square miles. Analyses of the ore show from 66 to 70 per cent. iron. The furnaces will have a capacity of 400 tons each. Except that the stove equipment will be larger than usual, American design will be followed throughout. Owing to cheap labor, it is estimated that pig-iron from these furnaces will be produced at a cost that would allow of its being delivered in New York at a lower price than the American-made product.—*Iron Trade Review.*

Cloud Negatives

(*Continued from page* 131)

negatives made at printing in other points than that represented by the foreground of the picture.

Landscape students will surely agree with him that the sky effects at a given point from an integral and characteristic portion of the landscape seen from that point, and that the sky effects of one district are quite different from those of another perhaps not distant district. When clouds from one landscape are transferred by "printing in" to a foreign landscape they lend that landscape a "foreign" character, better a hybrid character. The innocent purchaser undoubtedly is unable to perceive that the clouds have been printed in, when such is the case, but he derives a more or less erroneous impression from what purports to be the appearance of the locality portrayed.

Again the prevailing sky influences the shading, shadows, lighting of the landscape at the time the latter is photographed. Therefore it would seem that artistic work would require the sky expression to agree with the lighting of the landscape presented, and this requires that land and sky be photographed together and printed together.

To the student of science the artificial clouds are preferable to the hybrid landscape with foreign clouds "printed in." He recognizes the artificial clouds and pays them no more attention; if once he detects "printing in" of clouds he will reject both photograph and photographer as being unreliable and misleading.

Yttrium Mixed Metal

(*Continued from page* 139)

of metal present = 104.6) and 250 g. of cryolite. The charge was fused and electrolyzed in the usual way. Blank runs showed that with cryolite alone no aluminum was deposited. The cryolite dissolved the oxides completely although slowly, but the solution is not so good a conductor as well-made fused chlorides; the bath is much easier to prepare, however. During the electrolysis carbon monoxide was slowly evolved, and a great deal of "metal fog" was produced. More difficulty in separating metal and flux was also experienced. Runs were made using a current density of 55—65 amperes per sq. cm. at 12—13 volts; the temperature ranged from 1,200° to 1,300°. The metal produced was lighter in color than that produced by the other electrolyses, showed an "atomic weight" = 118.5 and contained 0.68% iron.

V. PROPERTIES OF "YTTRIUM MIXED METAL."

Considering the fact that no attempt was made to separate yttrium (Yt = 89) from the other earths (R = 152—174) associated with it, the average "atomic weight" of the metal produced (120) by the methods given is in no way different from what was expected. Other similar products prepared in future from "yttrium material" will just as certainly yield different "atomic weights" on account of the wide limits between which the composition of rare earth minerals varies. If, for the sake of convenience, we assume the atomic weight of yttrium = 90 and that of the non-yttrium portion = 150 (instead of 152, the lowest atomic weight of the associated earths) it is apparent that the value 120 for the "atomic weight" of the metallic product signifies a yttrium content of 50 atomic per cent; the percentage of yttrium by weight will then be 37.5.

The metal, separated as completely as possible from foreign material, was placed in a crucible of fused magnesia and sintered together in a vacuum furnace of the Arsem type, under a vacuum of one mm. or less. Accurate temperatures were not obtained; a pyrometer would not give trustworthy results with the furnace employed, owing to the constant variation in the intensity of the light within the furnace and a series of intermittent flashes across the carbon helix used as a heating element. This furnace will maintain a state of fusion with 600 g. of pure iron for an indefinite period when operating under a power of 10,800 watts; a power of 12,000-14,000 watts operating for nearly an hour only resulted in a sintering together of a 200 g. charge of yttrium mixed metal. While these results may be indicative of a high melting point, it must be remembered that the small amounts of oxide present could prevent coalescence in a relatively low-melting metal, as is true of aluminum and zinc.

The sintered metal was bluish gray in color, not of very high luster, although capable of taking a good polish; contact with air soon tarnished it. The sample examined contained 0.32% carbon and had $d^{16}/_{16} = 5.508$. It burns at a rather low temperature in the air, with a bright flash like magnesium, leaving a residue of light brown oxide. It is slowly oxidized by moist air at room temperatures. The powdered metal glows when heated in an atmosphere of hydrogen, nitrogen or carbon dioxide; the products of the first two reactions are pale yellow in color and the nitride(?) is readily hydrolyzed. The glowing in carbon dioxide is accompanied by the evolution of carbon monoxide. Neither powdered nor sintered metal shows any tendency to amalgamate with mercury. Both yield the characteristic "carbide odor" (*see ante*) although an odor somewhat suggestive of phosphine was noticed at times. As the metal decomposed water at room temperatures and contained carbon, hydrolysis of carbides contained in it is very likely the cause of the odor. The metal decomposes warm or hot water quite rapidly, and dilute acids react violently with it. A solution of 0.2 cu. cm. glacial acetic acid in 25 cu. cm. of 95% alcohol will "etch" the sintered material sufficiently for metallographic purposes in 10 seconds.

The sintered metal fell to pieces in time (even disintegrating to a powder) especially if exposed to the air. Grinding and rough polishing seemed to accelerate disintegration, most of the specimens behaving in this manner in course of preparation. Only two were obtained which could be studied, and these were highly unsatisfactory. Owing to the small size of specimens and the ease with which they disintegrated, hardness tests were deferred. The metal is with difficulty scratched with a file, although small pieces are pulled out by a file; it is pyrophoric, although not highly so in the sense of the modern "pyrophoric alloy."

Owing to the difficulties encountered in polishing (chipping out of small pieces, "dragging," scratching and tarnishing) satisfactory photomicrographs were not obtained. The rapid tarnishing prevents good definition. In general, the field was divided into two portions, one of which is dark and has somewhat the characteristic "eutectic structure" under the microscope. The other and lighter portion shows a complex structure of interlocked crystals, although not sharply defined. Unetched specimens did not yield photomicrographs owing to the ease with which the surface of the metal "dragged" under polishing. The darker component is the softer, the lighter crystalline material showing in relief after polishing.

Henry Hindley, the Inventor of the Hindley Worm-Gear

THERE have been many different statements made in the engineering press with regard to the inventor of the Hindley worm and gear. In a paper read before the Yorkshire Philosophical Society in England, by John Scott, some interesting information is given, based upon a thorough investigation into original sources. Henry Hindley was a noted clockmaker in York, England. He came to York about 1730, after having served his apprenticeship, it is believed, in Manchester. He died in 1771 at about seventy years of age.

One of his clocks is still in the Guildhall in York, and another in the Lord Mayor's House of the same city. Both clocks are keeping good time after 188 years of service. Another Hindley clock is installed at Clifton Castle. This clock goes for one year with one winding. It shows, besides the time of the day, also the date of the month, and is so arranged that it shows the correct date irrespective of the number of days in each month. It even has a correction for leap years.

Hindley's name has passed down in mechanical history not only as a clockmaker, but also as the inventor of the Hindley dividing engine, which was one of the first devices for accurately dividing a circle into any number of equal parts. In this device, he made use of the worm-gearing which has later been known by his name.

About 1785, John Smeaton, also a York man, wrote a paper to the Royal Society in which he stated that, in the autumn of 1741, he was first introduced to Henry Hindley, who had shown him his dividing engine, "at that time furnished with a dividing plate with a great variety of numbers for cutting the teeth of clock wheels, and also for more nice and curious purposes furnished with a wheel about 13 inches in diameter, very stout and strong, and cut into 360 teeth, to which was applied an endless screw adapted thereto; the threads of this crew were not formed upon a cylindric surface, but upon a solid, the sides of which were terminated by arcs of circles; the whole length contained fifteen threads, and as every thread on the side next the wheel pointed towards the center thereof, the whole fifteen were in contact together, and had been so ground with the wheel that to my great astonishment I found the screw would turn with the utmost freedom, interlocked with the teeth of the wheel, and would draw the wheel round without any shake or sticking, or the least sensation of inequality."

Further historical information relating to this eminent early mechanic could doubtless be obtained from the Yorkshire Philosophical Society, York, England, or from John Scott, 56 Thorpe St., Scarcroft Road, York, England.—*Machinery* (New York).

An Accurate Method of Measuring the Density of Gases

FOR the determination of the density of gases, a known volume of the gas at known pressure and temperature is liquefied in a small bulb attached to the containing vessel; the bulb is sealed off and the liquefied gas weighed at room temperature. The error in the method used was about 1 part in 2,000, but this could be reduced to less than 1 part in 10,000. The following values of density were obtained, the number in brackets being the value obtained by other investigators: acetylene, 1.1695; methyl ether, 2.1103 (2.1096); hydrogen bromide, 3.6397 (3.6438).—Note in *Sci. Abstr.* on paper by O. MAASS and J. RUSSELL, in *Jour. Amer. Chem. Soc.*

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